ALLEGHENY NATIONAL FOREST OIL HERITAGE
Warren
Warren County
Pennsylvania

HAER No. PA-436

HAER
PA
62-WAR,
3-

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Department of the Interior
1849 C Street, NW
Washington, DC 20240

ADDENDUM TO:
ALLEGHENY NATIONAL FOREST OIL HERITAGE
Warren vicinity
Warren County
Pennsylvania

HAER PA-436
PA,62-WAR,3-

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

HISTORIC AMERICAN ENGINEERING RECORD

ADDENDUM TO
ALLEGHENY NATIONAL FOREST OIL HERITAGE

HAER NO. PA-436

LOCATION: Warren vicinity, Warren County, Pennsylvania

SIGNIFICANCE: Western Pennsylvania is the birthplace of the modern petroleum industry, signified by the drilling of Edwin Drake's oil well near Titusville in 1859. Subsequent development of the Appalachian oil region, stretching from New York to Tennessee, revealed hundreds of oil fields that produced a particularly fine quality of petroleum, often called Pennsylvania Grade crude oil, that is still largely unsurpassed in its lubricating qualities. For thirty-five years, western Pennsylvania led the nation in petroleum production, and techniques of drilling and pumping oil perfected in Appalachia found usage around the world.

HISTORIAN: Michael W. Caplinger, 1997

PROJECT INFORMATION: The Allegheny National Forest Oil Heritage Recording Project was undertaken during the summer of 1997 by the Historic American Engineering Record (HAER, Eric DeLony, Chief), a long range program to document historically significant engineering, industrial and maritime works in the United States. The program is part of the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER) Division of the National Park Service, U.S. Department of the Interior. This project was sponsored by cooperative agreements between HABS/HAER, E. Blaine Cliver, Chief; the West Virginia University Institute for the History of Technology and Industrial Archaeology (IHTIA), Dr. Emory Kemp, Director; and Allegheny National Forest (ANF), a unit of the Eastern Region of the U.S. Department of Agriculture (USDA) Forest Service, John Palmer, Supervisor. The Southwestern Pennsylvania Heritage Preservation Commission, Randy Cooley, Director, provided major funding.

The field work, measured drawings, historical reports and photographs were prepared under the general direction of Christopher Marston, HAER Project Leader, with consultation from Phil Ross, ANF Historian. The field team was led by Eric Elmer, HAER Field Architect Supervisor and Michael Caplinger, IHTIA Historian. The team included Arturs Lapins, US/ICOMOS Intern (Latvia); and IHITA delineators Paul Boxley, Scott

Daley, Kara Hurst, and Kevin McClung. John T. Nicely produced the large format photography.

CHRONOLOGY

1854 Incorporation of the Pennsylvania Rock Oil Company

1858 Pennsylvania Rock Oil Company evolves into Seneca Oil Company and hires Edwin Drake to drill an oil well along Oil Creek, near Titusville

1859 Drake strikes oil, considered to mark the beginning of the modern petroleum industry, and the Appalachian oil region leads U.S. production for the next thirty-five years

1862 First attempts at constructing pipelines to transport oil and alleviate transportation

1863 Centrally powered pumping systems begin operation in the Appalachian region and southern Canada

1880 Oil pools in the Allegheny National Forest region flourishing

1890 Central powers common; Geer-Tiona central power constructed

1892 Pennsylvania produces 32 million barrels of oil, its all-time high

1895 Pumping engines converted from steam to well-head gas

1897 First bandwheel power patented

1909 Mead and Lockwood central powers constructed

1920 Golden Oil and McKenna-JoJo central powers constructed

1939 Mallory central power constructed

1950 Use of central powers declining in deference to self-contained “unit pumpers”

1980 Central powers largely abandoned by this time

1990 Pennsylvania’s oil production drops to just over 2 million barrels annually, about what the state produced in 1865

INTRODUCTION

Without petroleum, industrialized society would come to a grinding, screeching, friction-filled halt. Petroleum in its various forms is everywhere. It powers our engines, lubricates the moving parts of the world's machines, provides heat and light for millions, and its byproducts are the basic ingredient for hundreds of indispensable products. Its continued supply has even been deemed a strategic necessity and worthy of war. This most important substance is a gift of the earth. Like other valuable minerals, there is a finite amount of it, and it is found only in certain places. The Appalachian mountain region in the eastern United States is one of these areas, and western Pennsylvania is an especially important part. It was here that, on August 27, 1859, Edwin L. Drake successfully drilled a 69 1/2' deep well specifically to provide oil, thus ushering in the modern petroleum age.

The subsequent development of Pennsylvania's petroleum resources gave rise to fortunes, boomtowns, and an industry that remains active to this day. Speculators and wildcat drillers quickly moved to the formerly wild, sparsely populated regions of western Pennsylvania, and newly constructed railroads and pipelines vied for the petroleum trade. Pennsylvania supplied 98 percent of the nation's needs until 1886, when petroleum products from the Midwest and Southwest began dominating the industry. Even after this, the Appalachian oil fields continued to produce at a low level, buoyed by the higher-than-average price garnered for the superior-quality Pennsylvania Grade oil. For those interested in the technological aspects of crude oil production, the Appalachian oil fields, as the oldest developed oil fields in the country, provide a unique case study in the development of the petroleum industry, especially central-power well pumping systems.

THE ORIGIN AND NATURE OF PETROLEUM

Petroleum is the general term for a complex mixture of gaseous, solid, and liquid hydrocarbons.[1] It is a naturally occurring substance usually found trapped deep beneath the earth's surface, but at certain places it emanates from ground "seeps." These seeps were the first clue to petroleum's existence, and they supplied humans' need for "mineral oil" adequately for thousands of years. While there are many examples of petroleum's use in history, only the demands of the industrial revolution spurred systematic attempts to discover and produce oil and gas using relatively modern methods of drilling and pumping.[2] Until the drilling of Drake's well in 1859, the whale-

---

[1] Petroleum can be divided into a succession of hydrocarbon compounds through refining. At the top of the list are the lightest compounds, gases such as methane, followed by increasingly heavy compounds like gasoline, kerosene, fuel oil, lubricating oil, paraffin and asphalts. Those at the top are called the dry gases (highly flammable and odorless, non-liquefied), followed by slightly heavier wet gases, from which natural (liquid) gasoline is created by chilling, compression, or absorption. Below are the kerosenes (it and the liquid gases are collectively known as the naptha group), followed by fuel oils, then lubricating oils. The lowest and heaviest are called the semi-solids, including wax or paraffin oils, and asphalts. In addition to hydrocarbons, petroleum can contain up to 5 percent oxygen, 1.8 percent nitrogen, and 5 percent sulphur. See Max Ball, *This Fascinating Oil Business* (New York: The Bobbs-Merrill Company, 1940), pp. 21-24.

[2] The distillation of oil from asphalt-based petroleum was done in antiquity in the Middle East, and bitumens were long used to coat ship hulls. Animal and vegetable matter also produces oil through distillation. Coal-gas illumination gained great popularity in such cities as Baltimore, Boston and New York prior to the 1850s. Oils could be extracted from coal as well, a popular method prior to the success of Drake's Well. See Harold Williamson

oil industry supplied the market for illuminating and lubricating oil while the coal-gasification industry supplied gas. The depletion of whale populations and relative inefficiency of other chemical distillation methods spurred the search for mineral-based petroleum supplies. The origin and occurrence of petroleum within the earth has been the subject of debate ever since.

For many years, the discussion about the events that created and trapped petroleum produced widely varying theories. Today, the general opinion holds that petroleum formed from the decaying remains of organic material deposited hundreds of millions of years ago. Ancient seas and shorelines were the most likely spots for such deposits, where vast quantities of microscopic (and larger) marine life and plant material were collected and sealed into sedimentary layers, the source rock, to await decay.[3] The exact manner in which these organisms altered to petroleum is still somewhat vague, but far beneath the earth, heat, pressure, and possibly biological processes transformed the organic material into petroleum. Usually petroleum arising from the process migrated (horizontally and vertically) through porous rock layers, dissipating into the surrounding strata and atmosphere. Where the impervious cap rock overlays the source rock, reserves of petroleum are trapped and coalesce in a porous reservoir strata. This is often called a "pool," but the petroleum is usually not an underground lake, per se, but is still held within the rock matrix. This reservoir strata is nearly always sandstone, but it can be found in limestone, shale and other rock types.[4]

The tendency of petroleum to migrate to higher places in the rock usually resulted in a pool's gravitational separation into gas at the highest level, oil in the middle level, and water lowest down. In certain exceptions (the Pennsylvania fields are one), this clearly defined separation did not occur because of the relatively gentle folding of the subsurface strata and because of the cap rocks closely overlying the source rocks, which hampered vertical migration.

Petroleum reserves vary greatly in their makeup. Pools are sometimes entirely gas, but most often they are an oil and gas mixture. Logically, gas could migrate further than oil, and thus there are many gas-only pools in the otherwise mixed petroleum reserves of Appalachia and other petroleum producing regions. Chemically, local variations in both the original organic source material and the post-deposition transformation process account for the various petroleum types.

While chance and misguided theory largely governed attempts to locate petroleum prior to 1900, various scientifically based techniques could predict the location of structural and stratigraphic

---

and Arnold Daum, *The American Petroleum Industry: 1859-1899, The Age of Illumination* (Evanston: Northwestern University Press, 1959), Chapters 1-3.

[3] The salt inherent in such marine environments was also deposited in the rock. Its eventual mixture with ground water produced brine, from which the salt could be extracted. The salt industry, which arose in Appalachia in the early nineteenth century, developed the tools and techniques for brine well drilling that later made oil well drilling possible. In attempting to reach brine-bearing sands, salt drillers often lamented oil's presence, since it could foul the brine. This occurred so often that oil seeps were considered good indicators of brine deposits.

[4] Such sandstone layers are not always continuous, monolithic structures. The fact that most sandstone deposits originated as shoreline beaches and sand bars resulted in the formation of "lenses." These isolated, often elongated, formations can stretch for miles. Their thickness decreases near the edges until the formation is said to "lens out." The sandstone formations of Appalachia exhibit the lens characteristic.

traps that might overlie hidden reservoirs.[5] Geologists eventually accepted that several geologic conditions could form traps. Arched strata, such as anticlinal (upward) folds, were the most abundant of such natural traps, but traps could form in other ways, such as by a change in the porosity or density of the oil-bearing rock, salt domes, coral reefs, and impermeable faults. In Pennsylvania, however, the most common traps are anticlinal folds.[6]

This aspect of petroleum geology developed in the Appalachian region's oil fields, especially in West Virginia and Pennsylvania, which were intensely studied after 1859. In 1861, T. Sterry Hunt suggested a correlation between anticlinal features and petroleum. I.C. White, West Virginia State Geologist, published his own theory on anticlinal folding in 1885 after studying that state's Volcano oil field. However, this method of petroleum prospecting did not gain immediate acceptance. This was in large part due to the opposing views of Pennsylvania geologists John Carll, of the Second Pennsylvania Survey, and J.P. Lesley, the Pennsylvania State Geologist. Basing their opinions on conditions in western Pennsylvania, they considered the natural porosity of sandstones alone sufficient to account for petroleum accumulations in Appalachia. Both views were correct in certain aspects. Throughout the late eighteenth century and into the twentieth, however, drillers mistrusted or scoffed at the scientific methods and used wildcat wells to uncover new fields. White's anticlinal theory gained wide acceptance following its use in discovering the vast petroleum fields in the Southwest at the turn of the century.

Even with the success of anticlinal theory, locating oil was still a hit-or-miss prospect. For one thing, drilling was still required to determine if a structural trap held oil. Fortunately, drilling became easier, and drillers could penetrate great depths. Since the 1940s, offshore drilling and production have added even greater challenges to the petroleum prospector. Twentieth century geophysics has produced magnetic, seismic, and gravitational tests and remote-sensing techniques that can indicate the presence of favorable subsurface traps that may contain oil. The development of aerial and space-based photography has provided more tools for the modern petroleum geologist.[7] Today, petroleum is produced around the world, and scientists predict that the currently recoverable petroleum reserves will last at least another century.

THE APPALACHIAN OIL REGION'S HISTORIC ROLE IN NATIONAL PRODUCTION

North America possesses several distinct petroleum producing regions. The historic development of production from the United States' various fields followed a general east-west trend, beginning with the Appalachian district.[8] The districts vary widely in the type and amount

---

[5] The "belt theory" was one such misguided theory popular in the oil fields of northwestern Pennsylvania. It arose out of an incorrect interpretation of the lens phenomenon.

[6] W.A. Ver Wiebe, *North American Petroleum* (Ann Arbor: Edwards Brothers, 1957), p. 2. There are numerous reference works on the general origins and nature of oil.

[7] Even today, wildcat distillers discover some fields by chance. Regardless, 99 percent of all wildcat wells are dry holes.

[8] David Levin, *Petroleum Encyclopedia* (New York: The Ranger Press, 1942), p. 93. Eventually, the lower forty-eight states' major producing districts consisted of: the Appalachian district; the Lima-Indiana district, consisting of northwest Ohio and northeast Indiana; the Michigan district; the Illinois-Southwest Indiana district, consisting of Illinois, Western Kentucky, and part of Indiana; the Mid-Continent district, embracing Oklahoma, Texas (except the

of petroleum produced, overall production trends, and the makeup of the oil producing geologic formations. Most of these regions were discovered prior to 1900, but with Appalachia supplying nearly all the country's petroleum needs, most other fields produced at only a very low level for many years before reaching their highest output after the turn of the century.

In 1859, Edwin Drake's oil well near Titusville began large-scale development in the Appalachian Mountains, the nation's first and longest producing oil region.[9] The Appalachian oil fields were found to extend in a long, thin belt lying on a northeast to southwest axis along the western flanks of the Allegheny Plateau from western New York, through western Pennsylvania, western West Virginia, east Ohio and east Kentucky, to east Tennessee. Geologically, the district lies in the Appalachian geosyncline, or Appalachian basin, in which Paleozoic sedimentary deposits laid down during the Mississippian (280-345 million years ago) and Pennsylvanian (345-400 million years ago) periods dominate. The basin stretches from New York to Alabama and is bounded by the Appalachian Mountains to the east and a formation called the Cincinnati arch to the west in central Ohio.

Nearly all the oil and gas in the region is recovered from sandstone reservoir rocks. Most often these reservoir sands are located at the boundary of the lower Mississippian and Upper Devonian systems. Usually the oil pools are found in anticlinal folds (some synclinal folds also produce oil here) and the depth of producing sands range from just a few feet to about 4,000' below the surface. The average depth is about 1,800'. In the last thirty years, advances in drilling technologies have allowed discoveries of gas fields trapped in much deeper formations of 7,500' and more below the surface. Generally, production and drilling techniques were similar throughout the region.

The fact that the Appalachian oil region was the nation's first producing field is not surprising. Native Americans had known of the oil seeps of western New York and Pennsylvania, and had made use of them for hundreds of years. Europeans first noted the occurrence of oil in the region in the 1600s. Then the rise of the salt industry in West Virginia, Ohio, and Kentucky in the early 1800s provided a twofold stimulus. First, the Ruffner brothers in West Virginia's Kanawha Valley introduced the general technique of well-drilling in 1806, and these techniques became well-understood by many in the region. Second, oil was often found in brine wells and suggested that more might exist below in large quantities. Appalachia's relatively shallow oil fields facilitated their early discovery.

Gulf Coast), Kansas, northern Louisiana, Arkansas, and Missouri; the Gulf Coast district, including the Texas and Louisiana coasts; the Rocky Mountain district, covering Wyoming, Montana, Colorado, New Mexico, and Utah; and the California district. In the first years of the 1900s, the Mid-Continent, Gulf Coast and California fields far outpaced production in the rest of the country. There are various ways to delineate the nation's petroleum regions, such as by geologic formation, but most follow the "district" categorization. The terms districts, regions and fields are usually synonymous at this level.

[9] In some ways, this is misleading since oil was known to exist on many parts of the continents and had long been collected from various locales for medicinal purposes. Others were also drilling for oil in the Appalachians and Canada at nearly the same time as Drake. However, the completion of Drake's well is a convenient date, and it is widely considered the beginning of "industrial" large-scale production. For a countering view, see William McKain, *Where It All Began* (Parkersburg: McKain, 1995).

There were also other factors at work. The Appalachian oil region lay in close proximity to the major population centers of the east, with their demand for lamp oil and "medicinal" oil. Moreover, industrialization was underway there, requiring lubricants for machinery. Pioneer trunk line railroads had crossed the region in the preceding decade, linking the Atlantic with the Ohio River and providing unprecedented access to Appalachia's mineral wealth. The rapidly growing railroad network needed lubricants as well, adding to the growing pressure to find large, sustainable petroleum supplies.

The Appalachian fields began production in 1859 with 2,000 barrels of oil, increasing to over 2 million barrels a year in 1862.[10] Appalachia's production level steadily increased, and it remained the only field of importance until 1886, a year it produced nearly 27 million barrels, or about 98 percent of the nation's total.[11] After 1886, production leveled off in Appalachia and averaged around 30 million barrels a year, but this fulfilled the nation's demand adequately and relieved the pressure for increased production in the rest of the United States for another twenty years. Historically, Pennsylvania and West Virginia produced the large majority of Appalachia's total output, and New York the smallest fraction.

After the Appalachian field, the Lima-Indiana district was the next to rise to national importance with the discovery of large fields in northwest Ohio during 1886. Beginning with an average yearly production of over 1 million barrels, it did not immediately overwhelm the Appalachian fields in production totals, but afterwards the opening of this and other new districts continually wore away Appalachia's share of total output. By 1890, the Lima-Indiana district produced 15 million barrels yearly, compared to Appalachia's 30 million barrels. The nearby Illinois-Southwest Indiana district opened in 1889 with substantial production beginning around 1907 with over 24 million barrels.

During 1900, crude oil production in the United States amounted to nearly 64 million barrels, with Appalachia producing 57 percent, or 36 million barrels per year. This was Appalachia's peak production year. Afterwards, production in the East (the Appalachian, Lima-Indiana, and Illinois-Southwest Indiana districts) lessened in importance as the Mid-Continent, Gulf Coast, and California fields came to dominate.[12] Thereafter, production levels from the latter districts dwarfed those of the old eastern fields.

Appalachian oil dominated a special niche in the market as a high quality lubricating oil after 1900. Its usefulness as an aircraft-engine lubricant made it an especially valuable commodity as the century progressed. By 1930, the United States produced about 896 million barrels of oil a year with Appalachia supplying over 34 million barrels, or 3.8 percent of the nation's total. Up to that point, Appalachia had produced a total of 1.5 billion barrels, or 12 percent of the national

[10] One barrel equals 48 gallons.
[11] From 1860 onward, small production levels were seen in California (and Colorado the year after) but these were an insignificant fraction of Appalachia's and would not assume importance for another forty years. The Michigan district, discovered in 1865, was never a major producer.
[12] The large Mid-Continent district first opened in eastern Kansas and eastern Texas in 1889, but did not produce over a million barrels a year until 1903. It increased rapidly to over 123 million barrels a year by 1915. After producing negligible amounts for many years, the California district rose to prominence in the 1890s, surpassing Appalachia's production by 1905.

total production over seventy-one years.[13] By 1940, the United States produced well over a billion barrels a year, and Appalachia's share settled into an average contribution of around 2 percent, of which Pennsylvania was producing a full 1 percent. This breakdown of total production has remained largely unchanged since.

The demand for crude oil is a product of the oil's quality, which is usually determined by its "gravity" or weight. Low-gravity oils, while abundant, are in lower demand and cheaper. Higher-gravity oils are rarer and command a consistently higher price. The gravity measurement originally denoted "specific gravity" as determined by a water-displacement test, with heavier oils displacing more water, and the measurement reflected as a ratio of volume of oil versus water displacement, the lower figures being heavier oils. Later, a development called the Beaum (or A.P.I.) gravity scale reversed the measurement system, making larger numbers represent heavier oils. Pennsylvania Crude-standard oil had a specific gravity of about .8202 and an A.P.I. gravity of 41.0. The low specific gravity of Pennsylvania crude helped preserve production in the Appalachian oil fields and allow small-scale production by what would have been otherwise unprofitable wells. From a technological standpoint, this led to the development of ever-more efficient ways to pump wells, a fact discussed in more detail below.

Drilling and production in the United States have been governed by the price of oil, classic supply-and-demand responses to economic reality. After the initial discovery of oil at Drake's well in 1859, prices were up to $16.00 a barrel, but high production quickly lowered the price to a fraction of this. Appalachian oil averaged $1.80 a barrel after the initial period of extremely high prices, reaching a low of 56 cents per barrel in 1892 and a high of $5.35 a barrel in 1920. Between 1850 and 1930 the price of oil in the United States averaged $1.34 per barrel.[14] Well production in Appalachia averaged .6 barrels a day (the nation's lowest), while the national average was 8.4 barrels per day.[15] However, Appalachia's oil wells were the longest-lived in the country, and proved their worth in long-term production. On average, they returned 2.9 percent of their initial drilling cost per year.[16]

It should not be overlooked that, beginning in 1882 with the Appalachian region, these districts also commercially produced natural gas.[17] Practically all oil fields produce natural gas with the

[13] Ralph Arnold, *Petroleum in the United States and Possessions* (New York: Harper and Brothers Publishers, 1931), pp. 4-6. For yearly production totals of crude oil, see p. 33. Arnold's figures are based on those calculated by the U.S. Geological Survey yearly reports, Department of the Interior; and the U.S. Bureau of Mines yearly reports, Department of Commerce. Production totals vary from source to source and should not be considered exact, but they are a good indication of general production trends. Unless otherwise noted, production totals in this report are gleaned from the U.S. Bureau of Mines yearly reports, which provide a wealth of information.
[14] Ibid., p. 45.
[15] Ibid., p. 41.
[16] Ibid., p. 49. Between 1859 and 1930, there were about 600,000 wells drilled in proven areas of the United States, of which some 330,000 were producing at the end of this period. A large portion of the total number of wells, 242,479, were drilled in the Appalachian district (20 percent of these were dry holes). Of this number, 149,465 were still producing in 1930, and 93,041 had been abandoned. Over this seventy year period, the average cost for drilling and preparing a well for production in this region was $11,474.00 while the national average was just under $20,000.
[17] Natural gas usage began in Pennsylvania before 1882, but records on natural gas were not kept during this early period.

oil. Early in the industry's history, the gas was simply vented to the atmosphere or flared, and untold amounts were wasted. Between 1882 and 1928, the United States produced nearly 21 billion M cubic feet of natural gas. Three districts, the Appalachian, Mid-Continent (beginning in 1886), and California (beginning in 1889), produced approximately 95 percent of this total. Appalachia accounted for 53.6 percent, the Mid-Continent 33.5 percent, and California 7.9 percent of total production during this period. By 1930, however, Appalachia's yearly share of total production equaled only 21.8 percent, with the Mid-Continent producing 58.5 percent of the total.[18]

Appalachia also provided another valuable derivative of crude oil, automobile-grade gasoline. The rise of internal combustion engines and the advent of automobiles and airplanes created a previously non-existent demand for "natural-gas" gasoline. Between 1911 and 1928, the United States produced just over 10 billion gallons of natural-gas gasoline.[19] Again three fields dominated: the Mid-Continent produced 60.2 percent, California 24.6 percent, and Appalachia 11.7 percent of the total. In 1928, the Appalachian field produced 5.9 percent of the total yearly gasoline output.[20]

In summary, Appalachia was the most important oil region in the United States between 1859 and 1900. Pennsylvania produced the overwhelming majority of oil from the region, especially during the early years. Overall, between 1859 and 1928 Pennsylvania accounted for 53 percent of Appalachia's total production, followed by West Virginia (23.9 percent), Central and Southeast Ohio (11.4 percent), Kentucky (6.4 percent), New York (5.2 percent), and Tennessee (0.1 percent).[21] The development of central power systems and the suitability of Pennsylvania Grade crude oil for refining into lubricating oil helped insure its dominance of a small, but important, part of production in the United States.

BASIC OIL WELL DRILLING TECHNIQUES

The basic techniques of well drilling used in the early years of the Appalachian petroleum industry were adapted from salt and artesian well drilling. The simplest and most ancient method, springpole drilling, was inexpensive and required few specialized tools.[22] For springpole drilling, a stout but flexible tree trunk (the springpole) was propped-up in the center with a forked trunk, one end of the pole secured to the ground, and a rope attached to the end of the pole over the spot to be drilled. A heavy, iron, chisel-like drill bit was attached to the rope, along with an iron rod to add weight, and hung to the bedrock. Other short ropes attached to the springpole's free end allowed two to four men to simultaneously apply a quick downward bend to the pole, usually by stepping on a loop in the rope, dropping the iron bit against the ground with considerable force (this spawned the phrase, "kicking down a well"). With each blow, the bit shattered the rock, and the debris collected in the slowly deepening hole. Every so often the

---

[18] Arnold, *Petroleum*, p. 34.
[19] Pennsylvania began production of natural gas-gasoline around 1904 near Titusville, but records were not kept until 1911.
[20] Arnold, *Petroleum*, p. 36.
[21] Ibid., p. 64.
[22] The Chinese were drilling brine wells with springpoles as early as 221 B.C.

bit was removed from the well, and a "bailer" lowered to the bottom to retrieve the debris.[23] Once the hold was cleaned out, the drilling rope was lengthened, the iron bit was dropped back into the well to continue drilling, and the process was repeated. Although labor intensive, a springpole could drill a well hundreds of feet deep. It was particularly effective in Appalachia's relatively shallow producing sandstones.

An additional development in 1806 by the Ruffner brothers in (West) Virginia's Kanawah Valley was the conductor pipe, an essential component for successful wells. They found that unwanted ground water diluted the deeper brines they were trying to reach. The Ruffners solved this by using a hollowed-out log to line their drill hole down to the bedrock, where the ground water was sealed out. This allowed the hole to be drilled deeper to the brine-bearing sandstones without groundwater interference. This conductor pipe also prevented the hole from caving in and protected the hole from the rope and down-hole tools. Metal pipe eventually replaced the wooden tubing. This gave rise to the "drive pipe," which could be driven far down into the hole below the conductor to further protect the hole's sides from raveling.

During the salt- and artesian-drilling era, the techniques of springpole drilling were refined and mechanized, and steam power was adopted. Cable-tool (or percussion) drilling, as the most popular technique came to be known, made drilling even deep wells vastly easier.[24] Cable-tool drilling got its name from the "string of tools" that descended into the drill hole on the end of a hemp (later wire-rope) cable. A tool-string could be quite lengthy, up to 40' overall, and incorporated various components connected by box and pin sockets. For instance, one might consist of a 6'-long bit, a 25'-long drill stem (a heavy iron rod which added weight and increased drilling force), a set of "jars" (two giant, telescoping, interlocking iron links that would "jar" the bit loose from the rock, but also add a sudden dropping effect to the bit on the cable's downward plunge), and a socket mated with the hemp cable from which to hang the entire assembly. Derricks (at first only wood, but later all-metal) were required above the drill hole to hold a pulley sheave and a block and tackle. The 40' to 60' height of the derrick allowed the tool string to be raised clear of the hole and hang to one side while the bailer was swung over the hole and dropped into the well. A bewildering array of in-hole "fishing" tools and drive pipe underreamers were likewise developed.[25] Fishing tools could retrieve lost bits, cut drilling rope, cut casing, and perform seemingly impossible tasks far down in the hole. Sometimes fishing tools did not work, however, and a well had to be abandoned if a bit got stuck at the bottom, or the tool string could not be retrieved.

---

[23] A small amount of water is kept in the hole to aid drilling. Debris at the bottom mixed with water and formed a slurry, which the bailer or "sand pump" would lift out. Bailers were metal cylinders with a flapper valve on the lower end. The bailing operation also provided an opportunity to sharpen or replace worn drill bits.
[24] Even after the advent of mechanized cable-tool drilling, drillers who lacked the capital for a modern drilling outfit sometimes used springpoles. There were other methods as well, such as using wooden rods in place of the drilling cable.
[25] Underreamers would enlarge the diameter of the hole below the drive pipe so the pipe could be driven farther down.

In addition, by the time of the Drake's well, the surface machinery had taken on a modern appearance and the drilling process had become more involved.[26] Significantly, a steam engine and mechanical drilling rig replaced the springpole. A percussion cable-tool drilling rig's basic machinery consisted of the 1) engine and boiler; 2) derrick and crown block; 3) "bullwheel" and drilling cable; 4) "sandwheel" and "sanding line" for the bailer; 5) vertical "bandwheel" with a center crank; and 6) the "walking beam" supported by the "samson post." Bandwheels were essentially large pulleys, usually 8' to 10' in diameter, and driven via a leather belt from the engine, which reduced the engine r.p.m.s and increased power. A crank on the bandwheel's axle imparted up-and-down motion (via a pitman) to the walking beam, the other end of which was connected to the drilling cable by the "temper screw."[27] The walking beam alternately raised and lowered the drilling tools at the bottom of the well to perform the drilling.[28] Bullwheels and sandwheels were spools for the drilling cable and sanding line, respectively. In addition to the tool string, bailers and fishing tools, various hand tools, wrenches, and forge tools (to sharpen and repair bits, etc.) were required for the drilling process. Once the desired oil-bearing sand was found, the string of tools was removed and the well prepared for production--that is, if it was not a totally "dry hole."

Many different types of drilling rigs and derricks were eventually developed, including portable ones. The most popular non-portable rigs were the "standard rig" and the "California rig." The standard rig, the smallest type, was used mostly in Appalachia.[29] The larger "California rig" and even larger "California Imperial rig" were usually metal and used in the mid-western and western oil fields where deeper wells and different subsurface conditions required longer (and heavier) casings, and, in turn, taller, stronger derricks and more substantial machinery. By circa 1900, rotary drilling rigs were in use and eventually superseded cable tool drilling in most regions. During rotary drilling, water or mud compounds are pumped down through the hollow drill stem, through the drill bit, and back up the hole to the surface, carrying along the debris from the bottom of the hole. Cable tool drilling remained popular and adequate for most needs in Appalachia long after rotary rigs superseded its use in other regions.

AN OVERVIEW OF OIL PRODUCTION IN WESTERN PENNSYLVANIA

For purposes of analysis, the history of oil production in Pennsylvania can be divided into periods based on broad production trends: the preparation period (the decade prior to 1859); the pioneering period (from 1860 to 1886) when Pennsylvania supplied nearly all the nation's oil; the mature, settled-production period (from 1887 to 1922) when the state's production peaked but the industry expanded out of Appalachia and production levels began a steady decline; the

---

[26] For detailed descriptions of the drilling process and its machinery, see Raymond Bacon and William Hamor, *The American Petroleum Industry* (New York: McGraw-Hill, 1916), pp. 273-278, or especially J. E. Brantly, *History of Oil Well Drilling* (Houston, Texas: Gulf Publishing Company, 1971).

[27] The temper screw allowed the rope and the drill tools to be turned to ensure even drilling at the bottom of the hole. It also allowed the tools to be lowered slightly every few strokes without unhooking the walking beam.

[28] The crank could also be disconnected from the walking beam for a process called "spudding," which created the first 50' or so of a well until it was deep enough to hold the tool string and the hooked up walking beam. During spudding, a rope was connected to the drilling cable and tied directly to the crank. The crank jerked the rope on each revolution, which in turn jerked the drilling cable and caused the drill bit to rise and fall in the hole.

[29] Drake's drilling outfit fits the description of a standard rig.

period of secondary recovery and renewed exploration (1922 to 1941) when new methods of oil field rejuvenation temporarily increased production; and the modern period (since 1942), which has seen a slow but steady decline in production to current levels.[30]

Today it is known that Pennsylvania's oil fields run in a southwest to northeast belt through the western half of the state. The oil region encompasses, from north to south, Tioga, Potter, McKean, Warren, Crawford, Elk, Forest, Venango, Clarion, Jefferson, Armstrong, Butler, Mercer, Lawrence, Allegheny, Beaver, Washington, and Greene counties. The 300-plus oil pools that have been found in Pennsylvania are often grouped into four regions called--in order from northeast to southwest--the northern field, middle field, lower field, and southwestern field. The northern and middle fields have traditionally dominated production in the state.

The northern field lies on the border with New York, and consists of north and central McKean county and a small portion of Cattaraugus County, New York, and small outlying pools in Potter and Tioga counties. It was the second major field developed in Pennsylvania, after the lower field.[31] The middle field includes southern and western McKean County, Warren County (except the extreme southwestern section), northwestern Elk County, and northern and eastern Forest County.[32] The lower field encompasses western Forest, southwestern Warren, and all of Crawford, Venango, Armstrong and Butler counties (the lower field is home to Drake's well and many notable events in the early oil industry).[33] The southwestern field includes Beaver, Lawrence, Allegheny, Washington, and Greene counties.[34]

The story of Pennsylvania oil production goes farther back than Drake's 1859 well. Native-Americans and early settlers made use of mineral oil from Oil Creek (a tributary of the Allegheny River in northwest Pennsylvania) prior to the 1800s for medicinal purposes. The oil could reportedly cure rheumatism, arthritis, sprains and nearly every other human affliction. The development of a mineral-oil market in the East led to further investigation into its properties and possible uses during the years leading up to the establishment of Drake's well. These investigations focused on the seeps and oil springs in the Oil Creek region, which became central Franklin County.

---

[30] John Harper and Cheryl Cozart, *Oil and Gas Developments in Pennsylvania in 1990 with Ten-Year Review and Forecast* (Harrisburg: Pennsylvania Geologic Survey, 1992), p. 4.
[31] See the Appendix for a chronological listing by discovery date of Pennsylvania's oil pools. New York's Allegheny district is often included in the northern field but it never contributed more than 8 percent of the field's total output. The northern field includes the Bradford, Kinzua, Windfall Run, and Smithport pools.
[32] This region includes the Clarendon, Warren, North Warren, Balltown, Cooper, Sheffield, Glade Run, Stoneham, Tiona, Grand Valley, Sugar Run, Dew Drop, Wardwell, Kane and Elk pools. This region is sometimes further divided into the Warren district, Tiona district, and middle district.
[33] Among this region's major pools are: Tidioute, Titusville, Oil Creek, Tarkill, Bullion, Fagundus, Pithole, Cashup, Sugar Creek, Reno, Bradys Bend, Baldridge, Butler Cross Belt, Scrubgrass, Gas City, Enterprise, and Church Run. The Franklin district is considered a sub-district of the field because of its especially valuable lubricating oil.
[34] The southwestern field is made up of four smaller districts. The Beaver County district includes Beaver and Lawrence counties, in which the Smiths Ferry, Ohioville, Slipper Rock, and Freedom pools are found. Allegheny County and part of Washington County make up the Allegheny County district, which includes the Shannopin, Brush Creek, Milltown, McDonald and Gibsonia pools. The Washington County district stands alone and includes the Canonsburg, Burgettstown, Linden and Dague pools. Likewise, Greene County makes up its own district and includes the Blackshire, Fonner, Mt. Morris, Bristoria, Dunkard Creek and Ninevah pools.

Around 1848, Samuel Kier of Pittsburgh began selling bottled medicinal oil collected from his father's salt wells at Tarentum, Pennsylvania. Having burned the oil in the salt-making process at the plant, he knew its potential as an illuminant. He was soon able to distill it into an illuminating oil by removing some of its more objectionable qualities, such as the bad odor and soot created when burned. Kier quickly found a market for the oil in western Pennsylvania (especially Pittsburgh) and New York City, and its price rose from 75 cents to $2.00 per gallon. The Tarentum works and other skimming operations could not supply the increasing demand, however, and the push began for a stable supply.

About 1853, Francis Brewer, a Titusville doctor, carried an oil sample from the Brewer, Watson and Company farm on Oil Creek to Dartmouth College scientists for examination.[35] The scientists deemed it a valuable oil, fit for lubricating and illuminating purposes. While the sample was at Dartmouth, it happened into the possession of George Bissel, a New York lawyer, who became interested in its commercial possibilities. Bissel found a partner, Jonathan G. Eveleth, and immediately bought the Brewer and Watson Farm, forming the Pennsylvania Rock Oil Company of New York in December 1854. They took another oil sample to the prominent Yale scientist Benjamin Silliman, Jr., to further investigate the oil's properties. Silliman's April 1855 report confirmed the petroleum's high quality, described the distillation process required to produce illuminating oil (kerosene), and immediately created interest among other capitalists.[36] In Connecticut, Townsend persuaded an acquaintance, Edwin L. Drake, to purchase stock in the company. Drake became further involved and went to Titusville to examine the Brewer and Watson Farm. His report led to Bissel and Townsend appointing Drake as a general agent for the company. By March 1858, Bissel and Evenleth's company had evolved into the Seneca Oil Company of Connecticut.[37]

Drake returned to Titusville in 1859 and prepared to drill a well on the Brewer and Watson Farm. Drake had no experience in well drilling, so he hired a Tarentum blacksmith and salt-well driller, William A. "Uncle Billy" Smith, to aid in the operation. Drake erected an engine house and derrick, purchased a 6 horsepower horizontal steam engine, and set about sinking a drive pipe to the bedrock 32' below. Once they reached bedrock, they began to drill, averaging about 3' a day. On Saturday, August 28, 1859, Drake and his crew managed to drill to 69.5' with the tools removed. Upon visiting the well the next afternoon, Uncle Billy found oil floating atop water in the hole, completing the first step towards large-scale industrial production in the United States.[38] Thereafter, Drake's well produced less than 25 barrels of oil per day (BOPD). Through the end of 1859, oil sold at about $20.00 a barrel, and the Drake well represented a potential motherlode of profits. This did not last. The per-barrel price of oil quickly dropped into single figures with the sudden influx of supply.

Drake's well was an instant phenomenon. In response to the news, farms along Oil Creek were quickly bought up in hopes of similar success. In the mad search for oil-producing properties,

[35] This was a lumber company active along Oil Creek. They lit their mill with oil lamps by 1850.
[36] Silliman also noted the lubricating qualities of the oil.
[37] The company was organized in Connecticut because stockholders were better protected under that state's laws.
[38] This was in the Titusville pool.

proximity to Drake's well was the best indicator of probable success, and for the next five years the Oil Creek Valley was the center of intense activity among speculators, hopeful investors, and upstart oil-drillers. Former farms along Oil Creek, and up and down the Allegheny River from the mouth of Oil Creek at Oil City, were quickly bought or leased by prospective oil developers. Oil leases quickly became standardized, generally giving the landowners 1/8 of any profits generated by oil production on the property.

Drilling proceeded slowly, however, partly because of the difficulty in procuring equipment and manpower and partly because it was still a time-consuming process. Drillers using human-powered springpoles and scraped-together equipment immediately began drilling along the banks of Oil Creek, where again and again they struck oil. Only the unlucky came up dry. Ten producing wells were completed the next year, seventeen in 1861, twenty in 1862, and twenty-nine more in 1863.[39] Thus, of the 117 drilled to this time, seventy-seven struck oil and forty-one were dry holes. With the shallow wells costing just a few hundred dollars to drill and the high likelihood of success, it was a seductive business.

In the ensuing search for clues to subterranean oil, it was readily apparent from experiences with oil seeps and salt wells that oil was found in the presence of water. Furthermore, Drake had drilled his well just yards from the mouth of Oil Creek. This bolstered the notion that oil, like water, flowed below ground mimicking the topography of surface features. This led some to drill directly in the creek beds, until large mills began to be struck on the hilltops, thus subverting this theory. Such beliefs, born in Pennsylvania and followed by other pseudo-scientific methods such as dowsing and belt theory, would remain common until after the turn of the century.

The experience of successful (and unsuccessful) producers and wildcat drillers soon led to the study and mapping of northwestern Pennsylvania's oil fields, and the first attempts at explaining and predicting the presence of oil. Drillers concluded that oil was held in a series of three sandstone layers, and these oil sands were called, from top to bottom, the first, second and third oil sands, respectively. They were partially correct, but their system was too simple as there were many more than three oil bearing sands in the region.

Drake's well and the others that followed required pumping from the outset, but this soon changed. The first flowing well (in which pressure in the well forced the oil to the surface, sometimes spewing forth from the well head in the geysers) was struck on the Buchanan farm in the summer of 1860. With the sudden influx of supply, prices had fallen to a few dollars per barrel when, in April 1861 at nearby Rouseville, another well began producing prodigious amounts of oil.[40] It and subsequent wells in the area were spectacular, flowing over 1,000 barrels or more a day. However, after the initial outflow period, which could last months, flowing wells had the disheartening tendency to rapidly decrease production and require pumping, or stop production altogether. With flowing wells being discovered almost every

---

[39] J.D. Sisler, et al., *Contributions to Oil and Gas Geology of Western Pennsylvania* (Harrisburg: Pennsylvania Geological Survey, Fourth Series, Bulletin M19, 1933), p. 43.

[40] Rouseville was awash in oil upon the discovery of this well. Dozens of people were visiting the well site in mid-1861 when it caught fire. This inadvertent blaze killed nineteen people and destroyed a large part of the town. The early history of Pennsylvania oil production is replete with such conflagrations.

month, there was little reason to pump low-production wells, and oilmen simply moved on to drill a new well. For comparison, consider that Drake's well and one other completed on Oil Creek the same year produced about 2,000 barrels during the remainder of 1859.[41] Pennsylvania's output soared after 1859, to 500,000 barrels in 1860 and over 3 million by 1862. Small levels of production began in New York, West Virginia, Kentucky and Ohio, but Pennsylvania provided nearly all of Appalachia's total output for many years and likewise led the nation's production.

Some of these flowing wells along Oil Creek were legendary. The Funk (or Fountain) well produced 300 barrels a day for over a year before suddenly going dry. The Empire well, drilled in September 1861, produced 3,000 barrels a day for eight months, slowing to 1,200 barrels by May 1862 before production dropped to nothing. In October 1861, a well drilled by William Phillips on the Tarr farm on lower Oil Creek began flowing 4,000 barrels a day, making it probably the largest flowing well in the region's history.

Supply overwhelmed the limited demand for oil. Prices dropped to $1.75 per barrel in January 1861, to 10 cents by October, to as low as 5 cents per barrel before stabilizing.[42] Still, this price drop did not slow the quest for oil in northwestern Pennsylvania, or the rest of the country. Much oil and gas was wasted in this period, as there were often inadequate holding tanks or barrels on the site and the oil often flowed away into the creeks. By 1862, an estimated 10 million barrels of oil had been lost.[43]

There was also the intractable problem of transporting the oil to market. Lack of transportation links to the oil region meant that for the first years, much of the oil had to be hauled in barrels over poor roads in wagons to the nearest railhead or shipped by barge down Oil Creek to Oil City on the Allegheny River, and on to Pittsburgh, the major distribution point. Water fluctuations and winter ice complicated the latter route. The lack of rail connections also meant that equipment was often in short supply, spurring the rise of local manufacturers specializing in oil equipment and supplying the fledgling industry with drilling tools, steam engines and well pumping apparatus. Many related industries, such as barrel making and crude oil refining, prospered. The influx of oil workers to the region likewise supported industries that supplied food, clothing and entertainment. There were those who were striking it rich also, and reinvesting their money into more drilling and other aspects of the local economies.

The onset of the Civil War dampened development somewhat, and the unstable economic situation temporarily curtailed capitalist's drive to invest in the industry. Oil prices remained low throughout the first years of the Civil War, but began to recover in the latter years of the conflict. The glut of oil and extremely low prices brought oil producers along Oil Creek together to demand a steady minimum per-barrel price, at which they were somewhat successful. Prices rebounded, and by 1864 the oil fields of Pennsylvania were ripe for further development. The approaching end to the war set off a speculative boom.

---

[41] Complete production totals for Pennsylvania, 1859-1990, are included in the Appendix. Production figures were not accurately kept until 1876, so these early figures are estimates.
[42] Sisler, et al., *Contributions*, p. 57.
[43] Ibid., p. 64.

In addition, railroads began to enter the oil region, providing further impetus for development. Corry, in northwest Pennsylvania, was the nearest rail connection to Titusville. Both the Philadelphia & Erie and the Atlantic & Great Western railroads passed through the town. The Oil Creek Railroad ran 27 miles from Corry south to Titusville by 1862. It continued 2 miles on down Oil Creek as far as the Schaffer farm but no further. Beginning in 1862, the Atlantic & Great Western Railroad began building south from Corry to Meadville, reaching Franklin the next year and finally Oil City in March 1865.[44] The line continued to Pittsburgh in 1866, and other feeder lines began to spread through the region.

The major developments of the 1864-66 boom again occurred in and around the Oil Creek area as new pools were discovered. In 1864, Cherry Run, a branch of Oil Creek, became the first area of activity apart from the initial Oil Creek boom, followed in quick succession by Pithole Creek (a tributary emptying into the Allegheny River some 6 miles above Oil Creek); Benninghoff and Pioneer runs (both branches of Oil Creek) and Woods farm in 1865; the Stevenson farm in 1866; and the following year, Dennis Run, Triumph Hill (near Tidioute) and the Shamburgh well along upper Cherry Run.[45] Each time, a rush to develop the area followed news of the discovery, and boomtowns came and went with the flowing wells.

Pithole is the most famous of the early oil boom towns to spring up around a new producing area. Pithole began on January 8, 1865 with the United States, or Frazier, well striking oil on the Thomas Holmdon farm on Pithole Creek. By June, four wells produced about 2,000 barrels per day, or one-third the total output of the entire state. Other wells on this and surrounding tracts quickly began producing large amounts, and the city of Pithole sprang up overnight on the farm. Incredibly, by September of that year, Pithole had a population of at least 14,000 people, and the pool produced 6,000 barrels a day. The pool's high initial production dropped to almost nothing near the end of the year, and as activity peaked elsewhere, Pithole rapidly vanished.[46]

Despite the boomtowns, there was still the problem of getting the oil from the wells to the refinery or railroad. Oil pipelines, an important advance made during the 1860s, would have major future implications. Operators on Oil Creek were the first to attempt long-distance piping of oil. In 1862, L. Hutchinson used a short siphon-action pipeline on the Tarr farm to carry oil from his wells over a hill to a nearby refinery. The next year, a 3-mile pipeline was constructed from the Sherman well to the Miller farm on the Oil Creek Railroad. These early lines had technical problems, the most serious being leakage at the joints, and neither were successful. There was opposition too from the teamsters who made a living hauling the oil. Samuel Van Syckel of Titusville constructed the first practical pipeline using improved pipes connected with screw sockets and a pumping engine to force the oil through the line in 1865. It was a 4-mile line from Pithole to the Miller farm, carrying about 80 barrels of oil per day. Operator Henry

---

[44] Paul H. Giddens, *The Birth of the Oil Industry* (New York: The Macmillan Company, 1938), pp. 111-112. This book is one of the best histories concerning the early years of the petroleum industry in Pennsylvania.
[45] Bacon and Hamor, *The American Petroleum Industry*, pp. 219-220.
[46] Giddens, *Birth*, p. 140.

Harvey built another from Benninghoff Run to the Shaffer farm in 1866, and both of these were transferred to the Allegheny Transportation Company, which successfully operated the lines.[47]

Soon other lines were built and piping oil became its own industry, although at first the lines carried oil relatively short distances to refineries or railroad shipping points. By 1880, large companies like Standard Oil had become involved in pipeline construction and operation, laying an extensive network through the region that would eventually stretch between the Great Lakes and the eastern seaboard. This also affected the closure of many of the small local refineries in deference to large Great Lakes and coastal facilities. Pipelines became the preferred method of oil (and gas) conveyance for even long distances.

While the oil industry had enjoyed a period of higher prices during the Civil War, afterwards came the inevitable decline. During early 1865, oil sold for approximately $7.50 per barrel; by March 1866, it had dropped to $2.50. Low production wells were abandoned, and new drilling was curtailed as the industry entered a depression. It did not fully stop development though, and in 1866 new pools were discovered on West Hickory Creek and Dennis Run, and the town of Petroleum Center arose along middle Oil Creek near the mouth of Benninghoff Run. Only the most productive wells remained in operation as the depression continued through 1867.[48] Developments shifted south (down the Allegheny River) in the late 1860s with discoveries in Butler, Armstrong and Clarion counties. Wells had been drilled near the confluence of the Clarion and Allegheny rivers as early as 1863.

Wild price swings defined the 1860-1870 period. Largely the product of reckless stock speculation and a lack of regulation and organization of stock sales, producers and stockholders organized to rationalize production and prices. After tentative, mostly unsuccessful attempts at organizing in the mid 1860s, they formed the Petroleum Producers' Association of Pennsylvania in 1869, and by 1871, the establishment of oil stock "exchanges" such as Titusville Oil Exchange began stabilizing prices.[49] By 1873, prices were low (less than a dollar per barrel) but stable.

The economic situation improved, demand increased and production levels responded with prices remaining viable.[50] By 1876, the discoveries in the upper reaches of the Allegheny River's watershed around Bradford captured the industry's momentum. Wells had been drilled around Bradford in the early 1860s, but production was negligible until 1876. With the rush of development, Bradford became one of Pennsylvania's most significant pools and remained so through most of the twentieth century. In 1882, Pennsylvania produced a staggering 27 million

---

[47] Bacon and Hamor, *The American Petroleum Industry*, p. 247.
[48] Sisler, et al., *Contributions*, p. 43. By 1869, there were reportedly 1,186 producing wells in Pennsylvania, and 4,374 that had been dry holes or unprofitable and abandoned in the ten years since Drake's well.
[49] Giddens, *Birth*, pp. 190-191. Exchanges were eventually established at Oil City, Petroleum Center, Franklin, Titusville, Pittsburgh, and Bradford, and other cities in the oil region.
[50] Indeed, in the 1870s, there were across-the-board increases in output in each of the major fields. Per year production rose from 5 million barrels in 1870 to nearly 11 million barrels in 1874. After a slight drop in 1875 and 1876, output climbed to 13 million barrels in 1870, and by 1880 production had grown to 26 million barrels.

barrels yearly, of which the Bradford field alone accounted for 23 million, that field's historical peak.[51]

This period saw the rise of a particularly potent force in the petroleum industry, the Standard Oil Company. It played a major role in stabilizing the production and price swings prevalent from 1860 to 1880. During the late 1860s, John and William Rockefeller were active in the refining, shipping and selling of petroleum, primarily from the Ohio oil fields, but also from Pennsylvania and other states. The Rockefellers recognized that the industry needed a more stable price structure, as well as uniform standards for petroleum. In 1870, the Rockefellers (and other partners) created the Standard Oil Company of Ohio and began consolidating control over numerous companies.[52] They integrated the various aspects of oil production into a single company and built the most famous monopoly in American history. By 1882, through outright purchases and strategic agreements, the Standard Oil Company controlled much of the petroleum industry.[53] A trust agreement in 1882 among numerous companies resulted in the incorporation of Standard Oil Company entities in several states, each of which controlled the company's properties in that particular state. The Standard Oil Trust could not withstand the scrutiny of anti-monopoly sentiment, and in 1892 the federal government ordered the trust to liquidate. However, after some judicial wrangling, the company reincorporated as the Standard Oil Company of New Jersey in 1898 and continued operating until 1911 when Standard was finally broken into its thirty-three subsidiary companies. Although these companies were no longer controlled by Standard, for years after they were referred to as "Standard Oil Group."

From 1888 to 1922, Pennsylvania entered its mature production phase as the oil fields reached their maximum output.[54] Between 1888 and 1898, Pennsylvania's production remained at all-time highs—then came the inevitable slow decline.

In the middle field around Warren, Clarendon, Sheffield, and Kane, discoveries in the late 1870s and early 1880s helped spur the state's record high production levels. Numerous pools were discovered along the Tionesta Creek Valley, and on the vast, high plateau drained by the creek's

---

[51] Statewide production again fell for a few years, dropping to a low of 16 million barrels in 1888. Pennsylvania geologist J.F. Carll estimated that up to August 1887, 50,000 oil wells had been drilled in Pennsylvania (including the small section of New York in the northern fields).
[52] The Atlantic Refining Company was an early acquisition by Rockefeller. Incorporated in Pennsylvania in 1870, it operated refineries at Philadelphia, Pittsburgh, and Franklin and distributed petroleum in all cities and large towns in Pennsylvania and Delaware. This and related information on Standard Oil is from Bacon and Hamor, *The American Petroleum Industry*, pp. 260-261.
[53] In Pennsylvania, Standard Oil operated the National Transit Company, incorporated in 1881 with headquarters in Oil City. National Transit owned hundreds of miles of pipelines across Pennsylvania, and a network of feeder lines and storage installations in the western, oil-producing parts of the state. The company's lines also interconnected with those of Standard Oil controlled companies in Ohio, New York and New Jersey. There were several Standard Oil-controlled companies in Pennsylvania. South Penn Oil Company, incorporated in 1889 with a capital stock of $12.5 million, produced crude oil throughout Appalachia and was the leading producer-company in Pennsylvania's oil fields. The Galena-Signal Oil Company was another, incorporated in 1901 to manufacture lubricating and signal oils at plants in Franklin, Pennsylvania and surrounding states. For a complete listing of the Standard Oil Group, see Bacon and Hamor, *The American Petroleum Industry*, pp. 262-265.
[54] The Bradford field declined to just over 5 million barrels in 1890, yet the continual discovery of new pools increased overall totals. The all-time high, not surprisingly, was under the reign of Standard Oil.

various tributaries. The area's production averaged 400,000 barrels yearly through the period, reaching a high of 520,925 barrels in 1904. Some of the major pools in this area were the Warren, Wardwell, Morrison Run, and Dew Drop pools, along the Allegheny near Warren, and the Clarendon, Tiona, Cherry Grove, Cooper, Balltown, Sheffield, Watsonville-Klondike, and Kane pools along Tionesta Creek and its branches. This region is now part of the Allegheny National Forest and the sites recorded for this project are located in this area.[55]

Adding to the overall record highs, the lower district, which contained the old fields of Venango County along Oil Creek, as well as new pools in Beaver and Butler counties, also reached its record high, producing over 9 million barrels in 1891. In the southwestern district, beginning in the late 1880s, large-production wells were struck in Allegheny and northern Washington counties.[56] The MacDonald farm was the standout pool, producing a high of over 10 million barrels, or half the southwestern district's output, in 1891. Fortunately, the wild price fluctuations of the early years were a thing of the past, but oil remained cheap, less than $1 per barrel.

The high quantities produced in the new southwestern district pools, combined with flush production in the state's other fields, pushed Pennsylvania's production to its all-time record in 1892 of 32 million barrels. With the large supply, prices also bottomed out at 56 cents per barrel that year, before beginning a steady rise through the early twentieth century.

After 1892, developments in other parts of the country helped ensure a general decline in Pennsylvania's importance. Fewer new fields were discovered in the state and the old fields were simply past their prime, dropping toward relatively miniscule outputs. Speculators, drillers, and operators continued their practice of relocating to new sources of petroleum in other parts of the country, especially the Mid-Continent and California oil fields. Up to the 1890s, Pennsylvania had been the number one producing state in the nation; by 1920, it was number ten.

The demand for oil increased, however, as automobiles and airplanes became popular in this country. Per-barrel prices rose to over $5.00 in 1920, the highest since the years just after Drake's well. The lower and southwestern fields were home to the most drilling activity between 1910 and 1920, but the northern fields of McKean, Venango, Forest, and Warren remained the most consistent producing counties as the twentieth century progressed. Regardless, Pennsylvania's output dropped from 13 million barrels in 1900 to less than 8 million in 1920.

While Pennsylvania's wells produced only small amounts by this time, the state's high-quality oil had found its permanent niche in the early twentieth century, supplying crude oil for refining into lubricants for the age of the auto. Pennsylvania's high quality oil had been recognized from the industry's beginnings, and its beneficial characteristics were a continual motivation for

[55] For a detailed history of oil production within the boundaries of Allegheny National Forest, see Phil Ross, *Allegheny Oil, The Historic Petroleum Industry in Allegheny National Forest* (USDA Forest Service, Eastern Region, Allegheny National Forest Heritage Publication No.1, 1996).

[56] The southwestern district was slow to develop. First activity was in Greene county, which produced 93,034 barrels in 1888 and nearly 1 million in 1890, after which production slowed to an average 500,000 barrels per year.

further development of the state's oil fields. Early in the twentieth century, Pennsylvania's producer organizations began touting "Pennsylvania Grade" crude oil as an advertising phrase, and it became the hallmark of superior quality lubricating oils. Importantly, numerous products could be easily distilled from the crude. While kerosene (for illumination) was the main distillate during the early years, lubricating oil became the primary, and most lucrative, focus of refiners.[57]

First used as a lubricant for steam engines, the importance of Pennsylvania grade oil only increased with the advent of internal combustion engines. Fortunately, Pennsylvania grade crude was molecularly suitable for refining into various high-quality gasolines and motor oils, and refiners were able to improve their techniques in order to provide such products. Finally, the advent of high-speed aircraft engines in the first years of the twentieth century required an extra-high quality lubricant, and again Pennsylvania grade crude was the ideal source.[58] The essential qualities required for airplane and automotive engines were adequate viscosity, high flash point, low volatility, low oxidation tendency, and low consumption. Pennsylvania's oil possessed all these characteristics, and by 1930, both the British Air Ministry and the U.S. Army had written specifications that effectively excluded all but Pennsylvania grade crude for their lubricating oil purchases.[59]

The refining industry in Pennsylvania had to meet these challenges, and by the 1920s, the trend was set for the remainder of the century. In western Pennsylvania, numerous small refineries operated using crude from the surrounding fields and specialized in manufacturing lubricating oils that supplied local, national and worldwide markets. A few large refineries in the Philadelphia area operating mostly on water-shipped import oil that went to supply the in-state and regional demand for lesser quality oils countered the smaller refineries. Pipelines from surrounding states supplied a fraction of the crude oil to the Pennsylvania refineries. By 1931, there were forty-nine refineries in the state, with a total daily crude-oil refining capacity of 251,530 barrels.[60]

To the surprise of many, the downward production trend so evident just prior to 1920 was quickly reversed by a new technological development. First in the Bradford field, new methods of oil field rejuvenation were put into use beginning in 1922. Generally called "secondary recovery," these entailed various techniques of artificially repressurizing the old fields by injecting water, air or gas into old wells, which forced more oil from the source rocks than would

[57] Dewitt T. Ring, "The Oil Industry in the Appalachia Region," *Appalachian Geological Society 1949 Bulletin* (Charleston, West Virginia: Charleston Printing Company, 1949), p. 278. Upon refining, a typical barrel of Pennsylvania grade crude produced (in 1949): 25 gallons of gasoline, 9 gallons of lubricant, .83 gallons of kerosene, 4.25 gallons of fuel oil, and 4.95 pounds of wax. Lubricating oil was the most commercially lucrative of these derivatives.
[58] Noel Robinson, "The Value of Lubricants Made from Pennsylvania Oil," *Proceedings of the First Petroleum and Natural-Gas Conference* (State College, Pennsylvania: The Pennsylvania State College Mineral Industries Experiment Station, Bulletin 9, 1930), pp. 70-71.
[59] Ibid., p. 77. Pennsylvania grade crude oil contains no commercially useful levels of sulphur or asphalt, and contains the highest percent of saturated hydrocarbons in any crude.
[60] O.G.R. Hopkins and A.B. Coons, "Petroleum," *Mineral Resources of the United States 1930* (Washington: U.S. Government Printing Office, 1932), p. 811.

naturally flow. Subsurface conditions and the nature of the producing sand largely governed the method of recovery. In the north, pumpers found the hard, fine grained sands of the Bradford field (and some smaller surrounding fields) particularly well-suited for water flooding. Those fields in southern Pennsylvania were more receptive to air or gas repressurization.[61] To repressurize a field, all of the drill holes tapping the pool had to be found and capped. Only certain strategically located wells were set-up for production, while some others were made pressure injection wells. A pumping engine forced water down the injection wells, pushing oil toward central producing well. The Bradford field was given stunning new life, and secondary recovery soon came into widespread use in Pennsylvania.[62] Even the oldest fields around Titusville saw renewed production levels, and the slow decline in production seen in the early twentieth century was reversed. From 8 million barrels in 1920, output increased to over 19 million barrels at its renewed peak in 1937, the state's highest level in the twentieth century.[63] Incredibly, with the onset of secondary recovery, the Bradford field produced roughly 80 percent of the state's crude oil for the next 70 years.

The coming war highlighted the importance of Pennsylvania crude. World War II was "the machine war" and showed that modern, mechanized armies relied on petroleum for success. World War II also illustrated the extent to which Pennsylvania crude had come to dominate the specialty lubricating oil market. With the state's crude making up such a large share of domestic lubricant production, it was strategically very important to the Allied war effort. During the U.S. involvement in the war, Pennsylvania produced nearly 24 million barrels of lubricants, or 15.8 percent of total lubricant output of the Untied States during the conflict. Aviation oil was probably the most important contribution. In the final six months of war, Pennsylvania grade oil accounted for 32 percent of all oils used by aviation branches.[64] However, the war did have a detrimental affect on Pennsylvania's oil industry. To supply the needs of the country's armies, the domestic trade was sacrificed, and it took some years for the overseas markets to stabilize after the war.

While the declining production levels had steadied somewhat during the war because of demand, the oversupply after the war removed any incentive for maintaining increased production. Also secondary recovery could retrieve only a finite amount of oil, and production experienced a downward trend after World War II. This time, there was no respite, even though new fields were discovered almost yearly, and crude oil production steadily dropped from nearly 18 million in 1940, to just under 12 million in 1950, 6 million in 1960, 4 million in 1970, to 3 million in 1990. The Bradford field finally dropped to only 17 percent of the state's total by 1990. The northern counties of Warren, Forest, Elk, McKean, and Venango remained the most important producers. Through this period, Pennsylvania's yearly production averaged slightly less than 1 percent of the nation's total output. Fortunately for operators, prices began creeping back up

---

[61] Clark F. Barb and Paul G. Shelley, "General Information Regarding Production of Pennsylvania Grade Crude Oil," *Production Data on Appalachian Oil Fields* (State College, Pennsylvania: The Pennsylvania State College Mineral Industries Experiment Station, 1930), p. 9.
[62] The high output during secondary recovery meant temporarily lower prices--$1.88 per barrel by 1937.
[63] Around this time (ca. 1929), there were about 78,000 producing wells in the state, and each well produced an average .3 barrels of oil per day. Some 5,000 had been abandoned since Drake's well. Total revenue from crude oil between 1859 and 1929 had been over $1 billion.
[64] Ring, *Appalachian Region*, p. 278.

after 1940, through the $4.00 range in the 1960s to $11.51 in 1976. The oil embargos of the 1970s, increased demand in the 1980s, and the Persian Gulf War in the early 1990s steadily pushed oil prices to unprecedented highs.[65] This long-term trend toward higher prices resulted in Pennsylvania in declining production levels but increasing overall profits during the latter part of the twentieth century. It also led to the interesting case of a late-nineteenth century technological development, the central power process of multiple oil-well pumping, used into the late twentieth century.

OIL WELL PUMPING AND CENTRAL POWER SYSTEMS[66]

While petroleum sometimes flowed from a well under its own pressure, this was not usually the case. Most successful oil wells in Appalachia followed a pattern of high initial production (sometimes hundreds of barrels per day per well) followed by a rapid drop off to a few barrels per day (or week) or nothing at all. Thereafter, the well had to be mechanically pumped to recover any oil. By the 1870s, the "standard" pumping outfit was in use in Pennsylvania. Much of the surface equipment used to drill a well (the engine, bandwheel, and walking beam) could be used to pump it. This was a one-engine-one-well system in which a steam-powered engine pumped a single well.

To pump a well, first a string of metal tubing, 2" to 3" in diameter, with a "valve barrel" at the bottom, was placed in the hole. Inside this tubing, a long string of "sucker rods" was hung to the bottom of the well where it was connected to a standing valve in the valve barrel. On the surface, the well was set up with a standard pumping outfit (for pumping the well "on the beam") consisting of a steam engine and boiler (located a short distance from the well in a protective wooden powerhouse to prevent accidental fires), a vertical wooden bandwheel/crank, and a stout wooden Samson post supporting the walking beam. This was a standard pumping outfit for single wells, and it was widely used in oil fields through the early twentieth century.[67]

To operate the rig, a pumper would fire the boiler and bring the steam up to working pressure. Once the engine started and came to proper speed, the pumper engaged the clutch mechanism to transfer power to the pulley. A leather belt transferred power from the pulley to the vertical wooden bandwheel, which turned a shaft and crank at its center point imparting up-and-down motion (via the "pitman" connecting rod) to one end of the walking beam, which a timber

[65] In 1981, the per-barrel price was over $36.33, and in 1990 averaged $22.94 when the Persian Gulf conflict returned it to the $30.00 range. However, prices quickly dropped through 1998 to its lowest levels since World War II.

[66] See Ross, *Allegheny Oil*. Ross' book is perhaps the best review of the historical development of central powers and much of the following is based on his work. H.C. George, *Surface Machinery and Methods for Oil-Well Pumping*, Bulletin 224, Bureau of Mines, Department of Interior (Washington, DC: Government Printing Office, 1925), gives the most detailed descriptions available of central power systems and related oil-well pumping machinery.

[67] Often, production equipment was scavenged and reused from elsewhere, a common practice in oil fields. See Winston Davis, "Salvaging Oil Field Equipment," *Proceedings of the Eighth Pennsylvania Mineral Industries Conference: Petroleum and Natural Gas Section* (State College, Pennsylvania: The Pennsylvania School of Mineral Industries, 1938), p. 1.

samson post supported at the fulcrum point.[68] The well-end of the walking beam connected to the "polished rod," which in turn connected (inside the "stuffing box" of the casing head's "working barrel") to the top of the string of sucker rods.[69] The casing head attached to the top of the well tubing, and was fitted with two or more take-off pipes that routed oil into the drainage lines and/or carried off gas. As the walking beam rocked up and down in roughly 16" strokes, the sucker rods likewise moved up and down to actuate the standing valves inside the valve barrel at the bottom of the hole. The oil was forced upward through the pipe in the small space between the sides of the pipe and the sucker rods and out through the casing head. Buildup of paraffin in the tubes, a broken sucker rod, or other problems could require the sucker rods and/or tubes to be "pulled" and cleaned or replaced. Therefore, the derrick used to drill the well was often left in place for use in pulling the rods or casing.

So equipped, the machinery could pump the oil out much faster than it seeped from the petroleum-bearing rocks at the bottom of the hole.[70] In the decade following Drake's well, there was little impetus for pumping low-production wells after their initial outflow, as new fields were continually being discovered and the drillers would simply move on to sink another well. There were exceptions, such as when the oil tapped by a well was of extremely high quality. With low oil prices, however, it cost too much to outfit and maintain an installation and employ a pumper to operate it at each well. As prices began to stabilize, pumping became more feasible and economizing the process became the key to profitability. This drive for efficiency resulted in the popularization of centrally powered multiple-well pumping systems.

One of the first known cases of the central power concept being used to pump oil occurred in the Oil Springs pool in West Virginia.[71] This pool produced an exceptionally good lubricating oil, but each well produced only a tiny amount, forcing the operators to resort to pumping thirteen wells with a single 15 horsepower steam engine. It was called a "telegraph" system, in which long, thin wooden rods, suspended by hangers from wooden poles, transmitted power (with a reciprocating horizontal motion of about 20") to the wells nearly a half mile away.[72]

---

[68] Along with reducing the engine pulley's r.p.m.s, the bandwheel's momentum helped smooth the transmission of the power from the engine to the walking beam.
[69] Sucker rods were usually 16' long and about 2" in diameter, made of hickory or ash (later all metal) and connected with metal box-and-pin screw joints.
[70] To increase production, a well could be "shot" or "torpedoed" with nitroglycerin to extensively fracture the oil sands at the bottom of the hole. Once fractured, the increased surface area could produce more oil. E.L. Roberts patented this technique in 1862, and the first attempt at torpedoing a well occurred in 1866 on the "Ladies" well, near Titusville. It and subsequent successes in the Pennsylvania fields made this a common practice in the industry, regardless of the dangers inherent in transporting and handling the extremely dangerous liquid. In the twentieth century, other methods of fracturing oil-bearing rocks were developed. Among these were hydro-fracturing, where water, oil or some other liquid was forced into the well at a very high pressure to crack the rock at the well bottom.
[71] As early as the sixteenth century, German mines used similar systems to transmit power to pumps, which removed water from the mine workings. See Diane Newell and Ralph Greenhill, *Survivals: Aspects of Industrial Archaeology in Ontario* (The Boston Mills Press, 1997), pp. 128-129.
[72] Ross, *Allegheny Oil*, pp. 62-63. In 1871, another system of multiple-well pumping was in use at Volcano, West Virginia, a few miles from the Oil Springs. This somewhat anomalous system was termed "endless wire" pumping. An endless loop of wire cable, guided by pulleys, transmitted the central engine's power to a standard bandwheel/walking beam arrangement at each well. HAER documented the remains of this system in 1971 with measured drawings and large format photography, see "West Oil Company Endless Wire Pumping Station," HAER No. WV-9.

At about the same time, around 1863, Canadian operator John Henry Fairbanks devised a "jerker" system in the oil fields of Ontario.[73] Two parallel rows of wooden rods were connected to two cranks powered from an engine, which set the rods moving back and forth. Like the telegraph system, wire swings dangling from wooden poles held the jerker lines off the ground. Horizontal oscillating wheels, called "field wheels" or "spiders," could change the direction of the two main jerker lines. Individual branches of jerker line ran off the field wheels also. Each single line connected to a pump jack, which converted the horizontal motion to the vertical motion needed to operate the sucker rods.[74] Optimally, jerker lines were "balanced" by matching each well with one in the opposite direction, so that when the sucker rods in one well raised (the upstroke), those in the opposite well lowered under their own weight (the downstroke), helping raise the rods in the well undergoing the upstroke. This helped minimize the load on the engine. Fairbanks' jerker system was the first direct precursor to the system later put to use and perfected in Pennsylvania.

In the United States, Edward Yates of Philadelphia patented a very similar system on May 28, 1879. Called the Yates' "push pull" power, it substituted iron rods for the wooden jerker lines of the Canadian system. These were called "rod line" systems, as old iron sucker rods were often recycled and used for the jerker lines.

During the 1870s, the first real trend toward central powers in Pennsylvania manifested itself in a different way—the use of a single boiler to supply steam via pipes out to a steam engine at each well. Increasingly, gas from a nearby well fired these boilers, not wood or coal. Then, a decrease in the value of oil in the early 1880s forced many pumpers to adopt the new central power idea to keep marginally productive wells active. By 1885, the Yates' style push-pull powers pumped many clusters of wells in the older established fields and remained popular up into the early twentieth century.

Two developments in particular brought the central power concept to its mature phase: the Allen patented geared power of 1885 and the Grimes patented bandwheel power of 1897. With these inventions, all the essential components of the mature central power system came in to common use in Pennsylvania: the prime mover, or engine; a power reduction/motion-conversion/power distribution unit (always called the "power" in oil field parlance, not to be confused with the engine or prime mover); the shackle lines (also called pull, jerker, or rod lines), which transmitted the motion from the power out to the pump jacks; the pump jacks, which converted the horizontal, reciprocating motion of the rod lines to vertical reciprocating motion; all to actuate the sucker rods and valves in the well that pumped the oil to the surface. The engine and power required a substantial concrete foundation to resist the immense strains put on the

---

[73] Ross, *Allegheny Oil*, p. 64. Called "jerker" lines because the wooden rods operated only in tension, each line (in a cycle opposite its counterpart) was alternately pulled by the engine and then returned mostly under the weight of the sucker rods in the well. Also see Newell and Greenhill, *Survivors*, Chapter 6, for a detailed description and history of the Fairbanks system, which is still in operation.

[74] Pump jacks, right-angle levers that pivot on the apex, take the place of the samson post/walking beam arrangement of one-engine one-well pumping. In 1877, Waldemar Plackross of Fagundus, Pennsylvania, patented the first pump jack.

machinery, and both were enclosed in a protective powerhouse. Powerhouses lessened the chance for fires, but also held spare parts, tools, and gave the pumper and machinery protection from the elements. These equipment conflagrations were generally called central powers, but the term "jack plant" was also common. With the advent of gas- and oil-powered engines in the mid-1890s, costs were further lowered since the engine was powered by gas produced from the very wells it was pumping—a sort of low-cost perpetual pumping machine that required comparatively little manpower or maintenance to keep it in operation. By 1900, numerous oil-well supply companies had developed standardized systems that could be purchased in part or whole.

Certain factors controlled the use of central powers. Only relatively shallow wells, less than 3,000' deep, were suitable. While up to forty shallow wells could theoretically be pumped by a well-balanced, high-powered system, fifteen to twenty was a more common number.[75] The wells also had to be relatively close, within a mile of each other. Although the shackle lines could be routed over and around difficult terrain, extreme topography could hinder their use and was sometimes better suited to individual wells pumping on the beam.

PRIME MOVERS

Some early central powers used animal power, but the steam engine quickly took over. Since Drake's well, steam engines were a common sight in the oil fields. They had first been used in the salt drilling industry, perhaps as early as the mid-1840s, and by the time of Drake's well in 1859, there were at least three different types of horizontal, single-cylinder engine/boiler combinations used for drilling.[76] By the early 1860s, they were used (with auxiliary equipment, as described earlier) to pump wells that could not (or had ceased to) flow under their own pressure.

From 1859 to around 1895, the only types of prime movers available were steam powered, but by 1900, the trend toward gas and oil powered engines was in full swing.[77] A gas pumping engine had important advantages over its steam counterpart. It could be fired with gas from a nearby wellhead, removing the need for labor to fire, supervise, and maintain the water boilers. They were more efficient, plus generally safer and simpler to operate than a steam engine. Gas engines closely resembled steam engines; indeed, the first gas engines were often "half-breed" engines, where a steam engine was converted to gas by replacing the cylinder head and a few

---

[75] See K.B. Nowels, "Surface and Subsurface Loads on Bandwheel Powers," *Proceedings of the Second Petroleum and Natural Gas Conference* (State College, Pennsylvania: The Pennsylvania State College, 1932). This is perhaps the only published scientific analysis of loads on bandwheel powers.

[76] J.E. Brantly, *History of Oil Well Drilling* (Houston: Gulf Publishing Company, 1971), p. 403. This is an excellent detailed historical study of all types of drilling equipment, including the development of oil-field engines.

[77] Steam engines continued to be used for drilling up into the 1920s. They could be more subtly controlled and could better handle power overloads than gas or oil engines. Also, their motion could be reversed easily, an important consideration for drilling because of the continual need to raise tools out of the borehole, or pull tubing or sucker rods.

minor parts.[78] This was much cheaper than buying a whole new engine and helped speed the transition to gas power during the 1890s.

Many oil well equipment manufacturers in Pennsylvania produced gas-powered pumping engines, and they became very popular throughout the nation's oil fields. These horizontal, semi-portable, single-cylinder engines became the mainstay of drillers and pumpers.[79] They ranged in size from 10 to 60 horsepower, with 20 to 35 horsepower being the most common used for pumping, and both two-cycle and four-cycle engines were used. One or two flywheels were attached to smooth the power transmission to the belting. For larger power plants, casing-head gas plants, or pipeline pumping plants, gas engines were built in larger sizes with much higher horsepower. These were often vertical engines with double or triple cylinders. Smaller gas engines (less than 10 horsepower) sometimes drove auxiliary pumps. On gas engines that were used for pumping and to pull tubing or swab a well, a reversing clutch could be installed to the side of the engine to facilitate reversing the engine's power. The only other option—removing, twisting and reattaching the power transmission belt—was a time-consuming process.

A pipe from a nearby casing head or separator tank carried gas to the powerhouse, first passing through a gasometer or regulator (these ensured a constant gas pressure), before continuing into the engine room and into the engine's cylinder. Gas pumping engines usually used "hot tube" ignition to ignite the fuel-air mixture in the cylinder, although engines with electrical sparkplug ignition were also developed and widely used. Gas engines were usually water cooled, with coolant water circulating through the water jacket surrounding the engine's cylinder and dispersing its heat by passing through a coolant reservoir tank, which could be located inside or outside the powerhouse. On larger engines, the pumper employed a small air compressor to charge a compressed-air reservoir bottle. When the engine was ready to be started again, the compressed air was injected into the cylinder to initially crank over the engine since the flywheels were too heavy to turn over manually. Engine speed for pumping usually averaged 180 to 250 r.p.m. and was kept within safe limits by a governor on the throttle valve.[80] Moving parts on engines (and other equipment) needed constant lubrication, and either site-feed, splash-feed, or force-feed systems kept friction to a minimum.

During the 1920s, electric motors were increasingly used to pump wells and eventually superseded traditional gas or oil engines. Electric power supplied from larger commercial/public power plants could actually be thought of as the ultimate central power. Electricity could run a

[78] The Carrothers-Fithian Company (later the Bessemer, then Cooper-Bessemer Company of Grove City, Pennsylvania) developed one of the first half-breed cylinder heads. The South Penn Oil Company alone placed some 10,000 Carrothers-Fithian half-breed cylinders on their pumping outfits in Pennsylvania and West Virginia. See David Keller, *Cooper Industries 1833-1983* (Athens: Ohio University Press, 1983), pp. 33-34. Manufacturer B.D. Tillinghast of McDonald, Pennsylvania, developed a dual gas and steam engine, which could be converted at will without major modifications. Often the steam engine cylinder was used to drill a well, and the gas cylinder used for pumping.
[79] Pennsylvania was home to some of the country's most successful steam and gas engine manufacturers, supplying the needs of the oil industry around the world. Reid, Cooper-Bessemer, Bovaird & Seyfang, Franklin, Farrar & Tefts, were popular Pennsylvania-based engine producers.
[80] George, *Surface Machinery*, p. 24.

multi-well jack plant, or just a single well with unit pumpers powered by an electrical motor running off the local power grid.

POWERS

The r.p.m. reduction/motion conversion/power distribution unit, or power, was the key piece of equipment in central power systems. It converted the engine's rotary motion from, for example, 180 r.p.m. into a reciprocating motion of about 16 to 20 oscillations per minute that pulled the attached shackle lines an equal number of times.[81] Three different types of power were developed and in common use by 1900: the push-pull power, the geared power, and the bandwheel power.

Push-pull powers, described earlier, developed first. Initially, they were wood with some metal fittings. Wood construction was problematic, though, as wear, shrinkage, and loosening of the various fittings made them hard to keep properly adjusted. Eventually, all metal push-pull powers were developed that alleviated this problem, and they were used into the early twentieth century.

Geared powers came in three different configurations: the spur gear and crank-arm type, the bevel gear and disc type, and the bevel gear and eccentric type.[82] Pennsylvanian George Allen invented the first geared power, which actually became the core design behind all three configurations. Allen was in the refining business in Franklin, Pennsylvania, when he began designing his "Device for converting Motion in Oil Pumping Apparatus," otherwise known as a power.[83] A pulley-driven bevel gear that turned a vertical shaft on which a crank, disc, or "eccentric" was mounted, offset, to create the reciprocal motion needed to give a 15" to 20" arc of travel to the attached shackle lines. Allen's design was much cheaper than push-pull powers, and geared powers became very common in Pennsylvania. Geared powers varied widely in their frame design (which could be wood, cast iron, steel or a combination thereof), bracing, the layout of the reduction gearing, and the number and configuration of cranks, disks, or eccentrics. Bevel gear and eccentric type was probably the most popular in Pennsylvania. Depending on the number of wells to be pumped, one, two, or three eccentrics could be used. To properly balance the loads on the machine, two eccentrics were generally placed 180 degrees apart, and three eccentrics 120 degrees apart.[84] Eccentrics could be placed above the gearing (called overpull) or below the gearing (called underpull). Although underpull eccentrics performed better and required less bracing, overpull eccentrics allowed the shackle lines to exit the powerhouse higher off the ground, an advantage in rough or brushy areas.

Bandwheel powers were equally common in Pennsylvania oil fields. George Grimes patented the first bandwheel power in 1897. Similar to the vertical bandwheel used in drilling and pumping wells on the beam, bandwheel powers were wooden wheels 12' to 20' in diameter, except they were placed horizontally, mounted on a vertical steel shaft. Eccentrics, each with a

---

[81] George, *Surface Machinery*, p. 69.
[82] Ibid.
[83] Ross, *Allegheny Oil*, p. 66.
[84] George, *Surface Machinery*, p. 73.

"slip ring," were placed either above (overpull) or below (underpull) the bandwheel. A bandwheel was essentially a large pulley driven by a leather belt (from the engine) running around the face of its outer rim, negating the need for the bevel gearing. While its main function was to reduce the engine's r.p.m., the wheel's momentum also made it function as a flywheel, smoothing out any dead spots in the engine's power cycle and adding torque to the pull on the shackle lines.[85] Bandwheels were good for operating a large number of wells, but they required very heavy foundations and bracing. As such, they were usually only used on larger operations. Like geared powers, up to three eccentrics could be mounted on the central shaft. The slip ring around the outer edge of the eccentric was perforated for attaching the shackle lines, and as the eccentric turned, the slip ring imparted a straight back-and-forth motion to the shackle lines.[86] Bandwheels used a longer leather belt than geared powers, requiring an idler midway between the engine and bandwheel to maintain proper belt tension. Steel bandwheels were introduced in a 1913 patent for Wilbur O. Platt, President of the Joseph Reid Gas Engine Company.[87] These were usually preferred because they were lighter, operated more smoothly, caused less wear on the belting, and were more rigid. Also, they were prefabricated, making for easier transport and construction than wooden bandwheels.

Bandwheel powers were first designed for mounting in the horizontal plane, but the topography of Appalachia soon resulted in the "hillside power," a bandwheel mounted parallel with a hillside's slope.[88] The strains resulting from the tilted mounting required even heavier foundations and more consideration for balancing the load on the eccentrics.

SHACKLEWORK

Shackle lines, also called rod lines, jerker lines, or pull lines, connected to the power and transmitted the reciprocating motion of the eccentrics or cranks out to a pump jack at each well. Various devices supported and guided the shackle lines between the power and the pump jacks, keeping the line taut without hindering the transmission of power. Also, devices just outside the powerhouse allowed individual wells to be taken on or off the power. Older systems used wooden shackle lines, but wire cable to steel-rod lines performed better and became common after about 1900. Very often, old sucker rods were used for the shackle lines. Sucker rods and other wooden pull lines were usually hickory or ash octagon rods about 2" in diameter and 16' to 22' long, with forged wrought-iron couplings riveted to the ends.[89] They broke easily, however, and required frequent repairs and adjustments. Steel lines were round, 1' or less in diameter, and 20' to 30' long with upset ends so they could be connected with clamps. Since shackle lines operated only in tension, wire cable could be used as well for the entire shackle line or spliced into sections of steel rod lines. One or more turnbuckles along the shackle line allowed for adjustments in the line's tension.

---

[85] Ross, *Allegheny Oil*, pl. 67.
[86] Eccentrics without slip rings gave a side-to-side motion of 6" to 10" to the shackle lines along with the reciprocating movement.
[87] Ross, *Allegheny Oil*, p. 67.
[88] See "Geer-Tiona Lot 202 Lease," HAER No. PA-441.
[89] George, *Surface Machinery*, p. 77.

Metal hangers (mounted every 20' to 30', either on poles, tripods, or tree limbs) that swung like a pendulum when the lines reciprocated supported each shackle line along its length.[90] Shackle lines could also be supported by "friction posts," which were usually short lengths of reused 2" pipe driven into the ground, or mounted on a pivoting base to allow a rocking motion. On friction posts, a grooved piece of wood (called a doll head) was attached to the top to support the rod line. The doll head was kept lubricated to minimize friction.

Specialized shackle line devices were needed for other purposes: taking a well off, or putting a well on, the power (either a "take-off post" or "hook-off rail"); guiding the shackle line up or down changes in elevation ("hold ups" and "hold downs"); and changing direction in the horizontal plane to carry the lines around the obstacles ("butterflies" or swings).[91] These various mechanisms could be made of wood, steel, old pipe or casing. Any combination of the various devices might be found along an individual shackle line.

Hook-off posts (sometimes called take-off posts) or hook-off rails kept the shackle line in a horizontal plane as it exited the powerhouse, minimizing side-to-side movement, and providing a point to attach or detach a shackle line from the power. At the take-off post, the initial 10'-long steel rod that attached to the eccentric could be hooked to or unhooked from, the shackle line. Hook-off rails performed a similar function; they were used when the rod lines exited the powerhouse from underslung eccentrics at a low level. Either a C-link or a two- or three-hook connector link connected the eccentric rod and shackle lines. When not hooked to a well, the eccentric rod was hooked to a counter weight to maintain a balanced load on the eccentrics, while the shackle line was hooked onto the "take-off rod" or guy cable mounted securely into the power's concrete foundation. If the eccentric rod was not connected to a counterweight, the well in the opposite direction was removed to maintain balance. The counter weights assumed various forms, but the basic concept was to attach a weight equal to the weight on the line when it was operating the well. The counterweight pivoted on a mounting, mimicking the pull (in both weight and motion) required for the pump jack that the power would otherwise be operating. Often the counterweights (stones, old drill bits, jars, etc.) were simply laid in a tilted, bathtub-sized box configured to pivot on its lower end and called a "stone boat."

Shackle lines followed the contours of the land, without any long supportless gaps (say, hung across a valley), that would cause the line to sag and be robbed of its reciprocal motion. Hold-ups and hold-downs both moved with a pendulum (or rocking) motion, allowing the shackle line to reciprocate freely, but without any motion in the vertical plan that would decrease the stroke's length. Hold-ups (or "swing posts") were vertical posts mounted to a pivot on a ground plate or small foundation, with the top end connected to the rod line with stirrups and C-links. A hold-up would be used on a highpoint from a shackle line descended to resist the downward force created by the line's change to a downward direction. Conversely, a hold-down was a short pipe or pole, mounted similarly to a pendulum swing and located at a low point. The hold-down resisted any upward movement of the shackle line induced by a subsequent raising of the line's altitude.

---

[90] Poles, tripods and hangers, like most of the shackle line related equipment, could be built of wood or old pipe or casing. The operator usually fabricated them on site.
[91] George, *Surface Machinery*, pp. 76-87.

Changing direction in the horizontal plane required a "butterfly" (or horizontal swing, also called a hold-out) or "ring swing." A butterfly was a triangular wooden frame with one corner mounted (horizontally) to a pivot point (a tree or rock worked well), and the shackle lines connected to the remaining two corners. This allowed up to 90-degree turns in the shackle line and also provided another point at which other wells could be attached or taken off the power. A ring swing was simpler and used for lesser changes in direction. It consisted of three rings: one larger ring, attached to a suitable mounting spot (again, a tree or rock could be used as an anchor), and two smaller rings attached to the larger ring and connected to the shackle line.

AIR POWERS

"Air powers" or "air leases" were a rather anomalous development found particularly in the Bradford area of Pennsylvania. They appeared around 1920, but never gained wide use.[92] With this system, a centrally located gas engine powered an air compressor instead of the usual geared or bandwheel power; metal pipes or air hoses replaced the shackle lines. At the well heads, old steam engines were converted to pump jacks. Compressed air was sent through the pipes and injected into the steam engine cylinder, which powered a simple pitman/walking beam arrangement. These were called "Barcroft rigs" in Pennsylvania. There was also an "air-head" style pump jack, which was a compressed air actuated piston/cylinder supported above the well and connected to the sucker rods. The air power system had the benefit of fewer moving parts (meaning less maintenance and loss of power) and compared to shackle lines power could be transmitted over longer distances.

PUMP JACKS

A pump jack at each well converted the shackle line's horizontal reciprocating motion to a vertical reciprocating motion, which actuated the sucker rods, and in turn, the valves, in the well hole. After Plackross' invention of the pump jack in 1877, they assumed a wide variety of configurations but nearly all were classed as either "direct lift" or "indirect lift."[93] Manufacturers offered different types of jacks built either of wood, cast parts, structural steel I-beams, tubular steel, or a combination thereof.[94] Sometimes the operator used scavenged materials. Each type relied on a vertical triangular frame or "knee," with one corner connected to the shackle line, one to a pivot mount, and the other connected directly, or indirectly, through a steel pitman and walking beam arrangement, to the polished rod. On direct lift jacks, a curved mount at the polished rod-end of the knee (or walking-beam in the indirect type) allowed for a straight, vertical pull on the polished rod. Direct lift jacks were classed either as "underpull" or

---

[92] See "McKenna-JoJo Air Lease," HAER No. PA-442.

[93] Popular direct-lift jacks included the Hudson jack, Jones & Hammond jack, Simplex jack, Bessemer jack, and Norris jack. All were available from Pennsylvania's oil-well equipment suppliers. Indeed, indirect-lift jacks were sometimes called "Pennsylvania" jacks as they were first used in this state. The Oklahoma jack was the most popular type of indirect lift. Other types offered by manufacturers were the O.K. jack, the Paova jack, and the Maloney jack. Indirect-lift jacks were sometimes all referred to as "Oklahoma" jacks.

[94] Another type of jack, evidently not used in Pennsylvania, consisted of a grooved wheel mounted vertically, on which a cable shackle line made a 90-degree turn from horizontal to vertical and then attached to the polished rod.

"overpull" depending on the level at which the shackle line connected to the jack. Also, the length of the stroke imparted to the sucker rods could be adjusted at the jack.[95]

AUXILIARY EQUIPMENT

Cylindrical tanks in the vicinity of central power plants stored oil, cooling water for the engine, separated brine from the oil if the well made large amounts of water, or separated gas from the crude oil. Wood storage tanks (made of traditional iron hoops and staves) originated in the Pennsylvania oil fields around 1861 and remained popular until the 1920s and even longer in some areas. Riveted iron tanks gained popularity in the 1870s and were used through the 1920s. The bolted steel-plate tank, first used in the mid-1890s, and then the welded steel-plate tank in the mid-1920s superseded both the wood storage tanks and the riveted iron tanks. Iron and steel tanks both performed better than wood, but in some cases, wooden tanks were used through much of twentieth century.[96] Tanks came in a variety of diameters and heights, and like other well equipment, a variety of styles and types were often mixed together on the same operation. Sometimes old steam boilers turned on their end made smaller tanks.

Certain tanks separated gas vapor from the oil under low pressure so that it could be sent to the pumping engine or elsewhere. The first separator was introduced to the oil industry in the Oil Creek region of Pennsylvania in 1865. Separators operated by allowing the crude oil to flow from supply pipes into a chamber or tank. As the oil slowed and settled, the gas/oil mixture separated; the gas was collected and taken off through the top of the tank while the oil was taken off through a pipe at the bottom. Later, after 1900, high-pressure separators removed greater amounts of gas.[97] Other separators that could condense the gas vapor into liquid gas, or drip gas, took on the appearance of long horizontal tubes sealed at both ends, connected to supply and take-off pipes. While separators supplied cheap fuel for the engine, capturing and controlling the most gaseous contents of the oil also made accidental fires less likely.

POWERHOUSES

The "powerhouse" housed the engine, drive belt and power, although it could take on many different forms. Powerhouses originated with the earliest steam-powered drilling rigs, giving drillers and their engine a dry area in which to work. They were immediately adopted to house the pumping engine, belt, and vertical bandwheel when pumping wheels "on the beam." With the increase in equipment needed for central powers, the powerhouses expanded accordingly. They performed a variety of functions: protecting machinery, belting and laborers from the elements; storing tools, pipe fittings, and extra parts; and isolating the engine to decrease the chance of accidental fires.

Since the structure was built around the equipment, the machinery usually dictated the layout and size of the building. Through the late nineteenth century, powerhouses were built of wood. Some were built simply of notched logs, but most used balloon framing covered with siding

---

[95] George, *Surface Machinery*, pp. 86-89.
[96] D.V. Carter, et al., *History of Petroleum Engineering* (Dallas: Boyd Printing Co., 1961), pp. 710-716.
[97] Ibid., p. 717.

topped by shingled or tar paper roofs until around 1890 with the introduction of corrugated steel-sheet exteriors. Corrugated steel sheets became the covering material of choice by the early twentieth century. Some companies began using standard designs and materials, and complete prefabricated powerhouses became available from supply companies. Still, many remained idiosyncratic structures built on-site by the operator. Generally though, all were similar in that they were strictly utilitarian structures, usually rectangular, and built with economy in mind. Floors were often bare ground, but some had concrete floors in part, or all, of the building. The structure's foundations were usually minimal, but the machinery foundations could be quite substantial. Usually, interiors were sectioned, and tin sheeting completely covered the engine room's interior walls to prevent fires. Windows provided some light, but natural gas lighting was sometimes used. In colder climates, a small gas stove in the engine room kept the operator warm. If large machinery needed replacement, a section of wall would be removed, the new piece brought in, and the wall replaced.

Octagon-style powerhouses, a regional variant evidently found only in northwestern Pennsylvania, fall somewhere between standard and unique structures. An "octagon" powerhouse is similar to a normal powerhouse in every way, except that the room covering the power/eccentric unit is octagon-shaped in plan. These appeared in northwestern Pennsylvania around 1909 and were built, perhaps exclusively, by the South Penn Oil Company. Other than aesthetic quality, there are no currently agreed-upon explanations for this style of powerhouse. The following reasons seem to make the octagon power superior to the standard rectangular power, at least in Pennsylvania.

First, in addition to their elegant appearance, they were easy to construct. A building with an octagon plan contains eight identical rectangular wall panels of equal dimensions (one is left open in the interior into the beltway). Upon these, eight identical triangular roof panels sloping toward the center form a sectional cone.

Second, compared to a rectangular structure, an octagon provided more interior floor space around the circumference of the power, allowing the pumper to easily inspect, oil and repair the machine.

Third, viewed in elevation, the octagon presents a few clues as to the reason for its design. Always, one wall faces the viewer, and the slant of the conical roof draws the eye. Only in plan, however, does one plainly see the eight triangles that form the roof. Triangles are extremely rigid structural forms. In a standard hip roof, parallel triangles in a row along a central axis support the weight. Usually this is sufficient for most climatic situations, but under high winds, hip roofs are subject to axial weaknesses, i.e., the rafters can collapse on themselves like a deck of cards if the wind pushes hard enough from one end. Hip roofs are subject to extreme snow buildup, and the incumbent weight can overcome the load-sustaining capability of the roof. Great Lakes storms (lake effect snows) coming from the northwest routinely drop 30" of snow on this region. Equally violent storms periodically advance on this region from the south, west and east, a product of the area's northern latitude, mountainous plateau, and proximity to the

Atlantic Ocean.[98] An octagon's conical roof negates this threat, shedding wind and snow easily from all sides. Furthermore, the triangles making up the conical roof add their rigidity to the walls they rest on, an important factor considering that rods were often rubbing on the wall studs and cross members in a lateral motion (pulling on the walls, essentially). The structure around the power/eccentric continually underwent abuse from both Mother Nature and the motion of the shackle lines. The octagonal shape and the strength of the roof resisted these threats. Compared to a rectangular powerhouse, the octagonal powerhouse plainly appears more stable.

To summarize the octagon powerhouse design, its stealthy silhouette and strength must have made it superior to other powerhouse styles in this region. Its wind/snow footprint is minimized, and it exhibits inherent structural stability that helps it resist the strains produced by wind, snow buildup, and the machinery inside. Add to this the extreme severity of northwestern Pennsylvania's winters. One might suspect that octagons were used when the power was in a location particularly exposed to the elements, such as ridgetops, north facing hillsides, or open wind-swept areas. If this reasoning is correct, its design could be considered the penultimate in powerhouse engineering, forced by the unique conditions in northwestern Pennsylvania.

CONCLUSION

Powered pumping systems strove for efficiency, simplicity, and durability in the effort to maintain cost-efficient production levels. This seemingly straightforward concept behind central power systems required an ingenious combination of power reduction, directional change, and power-distribution apparatus to transmit a single engine's motive power to, ultimately, the bottoms of wells that might be located a mile away and 2,000' below ground. Their simplicity, efficiency, and reliability, combined with the high quality (and somewhat higher price) of Pennsylvania Grade oil and the general increase in crude oil prices throughout the twentieth century ensured their survival in Appalachia long after their period of common usage elsewhere. There are a few, very scattered examples of functioning central powers left today. The rest have been abandoned in the last thirty years. Even here, they are quickly disappearing from the landscape—unappreciated and misunderstood. While but one component of the overall petroleum industry, these fascinating machines and the creative minds that spawned them are key elements of our nation's oil heritage.

[98] All of the octagon powerhouses documented have roofs clad in wood shingles, which evidently perform better under high wind conditions (70 to 100 miles per hour) than asphalt shingles.

APPENDIX

The oil pools of Pennsylvania, listed by discovery dates up to 1928. These are not necessarily the flourishing dates of these pools.

DATE	NAME	COUNTY
1859	Titusville	Crawford
1860	Crooked Run	Butler
	Franklin	Venango
	Grand Valley	Warren
	North Warren	Warren
	Oil City	Venango
	Smiths Ferry	Beaver
	Tidioute	Warren
1861	Bradford	McKean
	Carmichaels	Greene
1865	Blackshire	Greene
	Northeast	Erie
	Pithole	Venango
	Pleasantville	Venango
1867	Dennis Run	Warren
	Oleopolis	Venango
	Shamburg	Venango
1869	Elk City	Clarion
	Petrolia	Butler
1870	Emlenton	Venango
	Fagundus	Warren
	Fosters	Venango
	Raymilton	Venango
	Sandy Creek	Venango
	West Hickory	Forest
	West Liberty	Butler
1871	Sugar Creek	Venango
1872	Cranberry	Venango
	Utica	Venango
1873	Concord	Butler
1874	Butler Cross Belt	Butler
1875	Bullion	Venango
	Glade Run	Warren
	Sheffield	Warren
	Smethport	McKean
	Summit	Butler
	Wardwell	Warren

	Winfield	Butler
1876	Economy	Beaver
	Garrison	Greene
	Glade Mills	Butler
	Kane	McKean
	Kennerdell	Venango
	Whitley Creek	Greene
1877	Cookson	Allegheny
	Lafayette	McKean
	Lake Creek	Crawford
	Tionesta	Forest
1878	Clarendon	Warren
	Cornplanter	Warren
	Kushequa	McKean
1879	Cherry Grove	Warren
1880	Dewdrop	Warren
1881	Mansen	Elk
	Sackett	Elk
1882	Shannopin	Beaver
1883	Balltown	Forest
1884	Homewood and Swissvale	Allegheny
	Thorn Creek	Butler
1885	New Galilee	Beaver
	Oneida	Butler
	Washington-Taylorstown	Washington
1886	Mount Morris	Greene
	Pleasant Unity	Westmoreland
	Saxonburg	Butler
1887	Clifton	Allegheny
	Fayette	Fayette
1888	Canonsburg	Washington
	Clarion	Clarion
	Hallton	Elk
	Masontown	Fayette
	Ninevah	Greene
	Shamburg	Clarion
1889	Hookstown	Beaver
	Waynesburg	Greene
	Wildwood	Allegheny
1890	Burgettstown	Washington
	Chartiers	Allegheny
	Coraopolis	Allegheny
	Florence	Allegheny

	Glade	Butler
	Mars	Butler
	McCurdy	Allegheny
	McDonald	Washington
	Richhill	Greene
	Slippery Rock	Lawrence
1891	Clintonville	Butler
	Moon	Allegheny
	Muddy Creek	Butler
1892	Evans City	Butler
1893	Garvin	Butler
	Keown	Allegheny
1894	Glenhazel	Elk
	Homestead	Allegheny
	Little Mud Lick Creek	Armstrong
	North Washington	Butler
	Ormsby	McKean
	Venice	Washington
1895	Glenfield	Allegheny
	Lickskillet	Allegheny
1896	Bristoria	Greene
	Criders	Butler
	New Freeport	Greene
	Rosenberg	Butler
1897	Crows Run	Beaver
	Fonner	Greene
	Grays Fork	Greene
1898	Bellevue	Allegheny
	Broadtree	Greene
	Imperial	Allegheny
1899	Ingomar	Allegheny
	Lagonda	Washington
	Lantz	Greene
	Moon Run	Allegheny
	Shellhammer	Armstrong
1900	Aleppo	Greene
	Aten	Allegheny
	Carnegie	Allegheny
	Deer Creek	Allegheny
	Grapeville-Arona	Westmoreland
	Hammersley Fork	Clinton
	Leechburg	Armstrong
	Linden	Washington

	New Castle	Lawrence
	Ross	Washington
	Sharon	Mercer
	St. Marys	Elk
	Zelienople	Butler
1902	Unionville	Butler
	Zollarsville	Washington
1905	Bolant	Mercer
	Woodruff	Greene
1906	Dague	Washington
	Miola	Clarion
1908	Pine Run	Westmoreland
1910	Bessemer	Lawrence
	Callery	Butler
	White Ash	Allegheny
1917	Clugston	Allegheny
	Hookstorm	Beaver
	Knoxville	Tioga
	Monaca	Beaver
	New Bethlehem	Clarion
1919	Bellsano	Cambria
	McKeesport	Allegheny
1924	Campbell Farm	Allegheny
	Perry Township	Greene
1925	Morris Township	Greene
	Rutan	Greene
1928	Atlantic	Crawford

BIBLIOGRAPHY

Arnold, Ralph and William Kemnitzer. *Petroleum in the United States and Possessions*. New York: Harper Brothers Publishers, 1931.

Bacon, Raymond Foss and William Hamor. *The American Petroleum Industry*. Volume I. New York: The McGraw-Hill Book Company, 1916.

Ball, Max. *This Fascinating Oil Business*. New York: The Bobbs-Merril Company, 1940.

Barb, Clark and Paul Shelley. "General Information Regarding Production of Pennsylvania Grade Crude Oil," in *Production Data on Appalachian Oil Fields*. The Pennsylvania State College Mineral Industries Experiment Station Bulletin 6. State College, Pennsylvania: School of Mineral Industries, 1930.

Beeby-Thompson, A. *Oil-Field Exploration and Development*. Volume I. London: The Technical Press Ltd., 1950.

Brantley, J.E. *History of Oil Well Drilling*. Houston, Texas: Gulf Publishing Company, 1971.

Carter, D.V., ed. *History of Petroleum Engineering*. The American Petroleum Institute. Dallas: Boyd Printing Company, 1961.

Crum, A.R., ed. *Romance of American Petroleum and Gas*. Volume I. Oil City, Pennsylvania: The Derrick Publishing Company, 1911.

Derrick's Hand-Book of Petroleum. Volume II. Oil City, Pennsylvania: The Derrick Publishing Company, 1900.

Davis, Winston. "Salvaging Oil Field Equipment," in *Proceedings of the Eighth Pennsylvania Mineral Industries Conference: Petroleum and Natural Gas Section*. The Pennsylvania State College Bulletin 25. State College, Pennsylvania: The Pennsylvania School of Mineral Industries, 1938.

Dickey, Parke. *Oil Geology of the Titusville Quadrangle, Pennsylvania*. Pennsylvania Geological Survey Bulletin M 22. Harrisburg: Commonwealth of Pennsylvania, 1941.

Fettke, Charles. *Bradford Oil Field-Pennsylvania and New York*. Pennsylvania Geological Survey, Fourth Series, Bulletin M 21. Harrisburg: Commonwealth of Pennsylvania, 1938.

George, H.C. *Surface Machinery and Methods for Oil-Well Pumping*. Department of the Interior Bureau of Mines Bulletin 224. Washington, DC: Government Printing Office, 1925.

Giddens, Paul. *The Birth of the Oil Industry*. New York: The MacMillan Company, 1938.

________. *Early Days of Oil*. New Jersey: Princeton University Press, 1948.

Hager, Dorsey. *Fundamentals of the Petroleum Industry*. New York: McGraw-Hill Book Company, 1939.

Harper, John and Cheryl Cozart. *Oil and Gas Developments in Pennsylvania in 1990 with Ten-Year Review and Forecast*. Pennsylvania Geological Survey, Fourth Series, Progress Report 204. Harrisburg: Commonwealth of Pennsylvania, 1992.

Hopkins, O.G.R. and A.B. Coons. "Petroleum," in *Mineral Resources of the United States*. U.S. Department of Commerce, Bureau of Mines. Washington, DC: Government Printing Office, 1930.

Illustrated Catalogue of the Oil Well Supply Company. Pittsburgh: The Oil Well Supply Company, 1892.

Keller, David. *Cooper Industries: 1833-1983*. Athens, Ohio: Ohio University Press, 1983.

Langley, Set. "Oil Well Pumping Methods and Equipment." *Engineering and Mining Journal*. 109, No. 13 (March 27, 1920): pp. 748-754.

Leven, David. *"Done in Oil": The Petroleum Encyclopedia*. New York: The Ranger Press, 1942.

Lytle, William. *Crude Oil Reserves of Pennsylvania*. Pennsylvania Geological Survey, Fourth Series, Bulletin M 32. Harrisburg, Pennsylvania Geological Survey, 1947.

________. *Oil and Gas Geology of the Warren Quadrangle, Pennsylvania*. Pennsylvania Geological Survey, Bulletin M 52. Harrisburg: Commonwealth of Pennsylvania, 1965.

Lytle, William and Joseph Goth. *Oil and Gas Geology of the Kinzua Quadrangle, Warren and McKean Counties, Pennsylvania*. Pennsylvania Geological Survey Mineral Resources Report 62. Harrisburg: Commonwealth of Pennsylvania, 1970.

The National Supply Company: Oil and Gas Well Supplies Catalogue. No. 14. Pittsburgh: The National Supply Company, 1906.

Nowels, K.B. "Surface and Sub-Surface Equipment Loads of Bandwheel Powers," in *Proceedings of the Second Petroleum and Natural Gas Conference*. The Pennsylvania State College Mineral Industries Experiment Station Bulletin 11. State College, Pennsylvania: The Pennsylvania State College School of Mineral Industries, 1932.